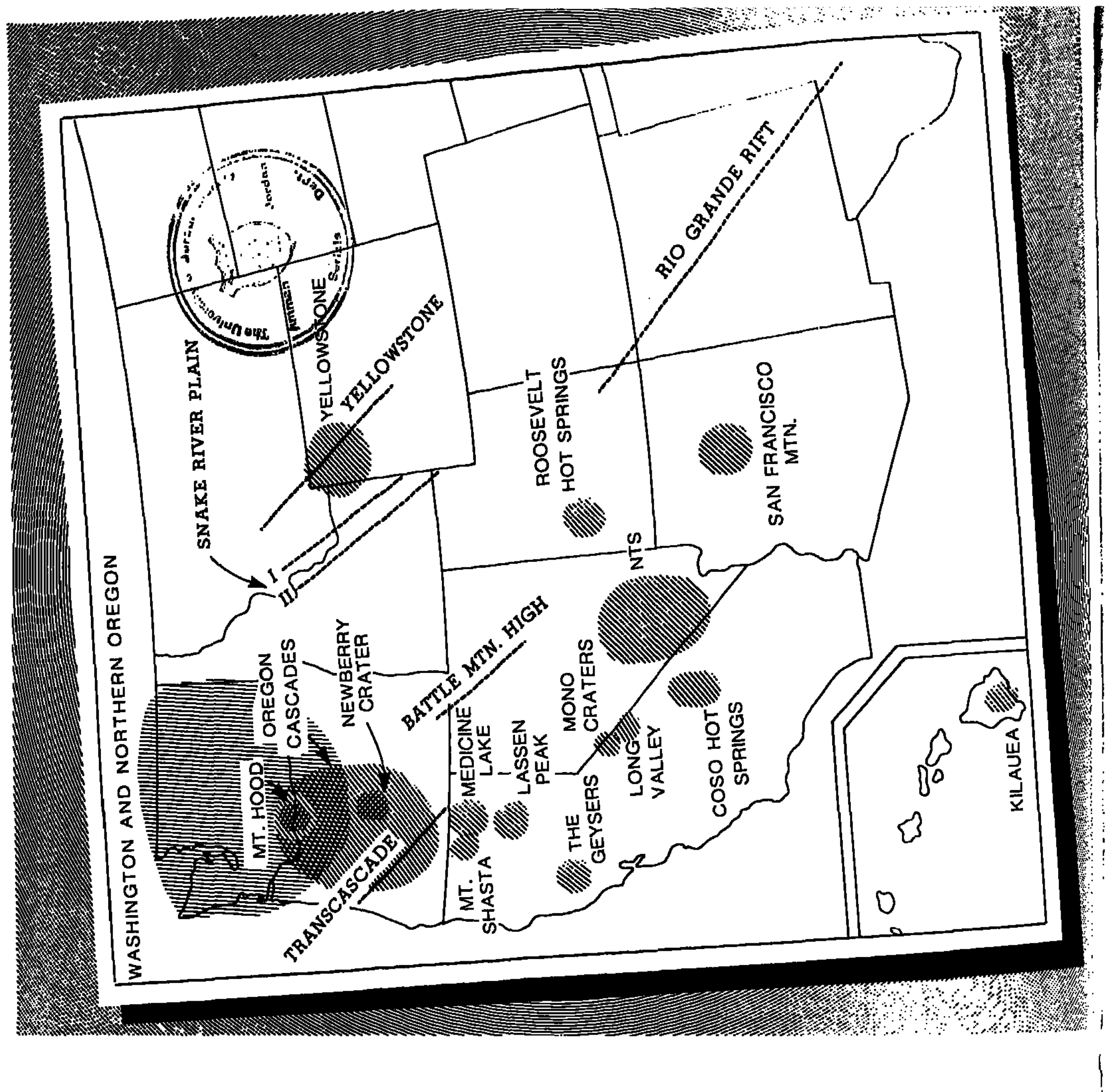


EOS
Transactions, American Geophysical Union
Vol. 65 No. 12 March 20, 1984

Eos, Transactions, American Geophysical Union Vol. 65, No. 12, Pages 105 – 112 March 20, 1984

Meteorology

Ocean Bottom Seismometer Technology

William A. Prothero, Jr.
Department of Geological Sciences
University of California
Santa Barbara, CA 93106

Seismometers have been placed on the ocean bottom for about 45 years, beginning with the work of *Ewing and Vine* [1938], and their current use to measure signals from earthquakes and explosions constitutes an important research method for seismological studies. Approximately 20 research groups are active in the United Kingdom, France, West Germany, Japan, Canada, and the United States. A review of ocean bottom seismometer (OBS) instrument characteristics and OBS scientific studies may be found in *Whitmarsh and Lilwall* [1984]. OBS instrumentation is also important for land seismology. The recording systems that have been developed have been generally more sophisticated than those available for land use, and several modern land seismic recording systems are based on OBS recording system designs.

The instrumentation developed for OBS work was the topic of a meeting held at the University of California, Santa Barbara, in July 1982. This article will discuss the state of the art of OBS Technology, some of the problems remaining to be solved, and some of the solutions proposed and implemented by OBS scientists and engineers. It is not intended as a comprehensive review of existing instrumentation.

The requirements for OBS capsules are similar to those for space satellites. They must be self contained, have a recovery method, and, usually, a communication system between the ship and the instrument. Reliability is a troublesome problem. Shipboard checkout, repair, and deployment must be streamlined as much as possible since multiple instrument deployments must be accomplished under often adverse conditions.

The typical OBS consists of a bouyant instrument capsule which is held on the bottom by some kind of anchor. It is deployed by dropping it over the side of a ship, whereupon it free-falls to the bottom. The electronics systems which log data, release the anchor, and communicate to the surface acoustically are contained within the pressure case. Both seismometers and hydrophones may be used as sensors. The coupling to the bottom is through the anchor, but schemes have been developed to separate seismometers from the main instrument case in order to improve the coupling to the bottom and reduce the coupling of vibrations between the tape recorder and seisometer(s). When it is time to retrieve the OBS, the anchor is separated from the buoyant instrument case using an explosive bolt, electrolytically dissolving wire, or mechanical actuator. The instrument case then floats to the surface, where it is retrieved. The following sections will describe each aspect of various OBS in more detail.

OBS Pressure Container

Both tubes and spheres have been used as pressure containers. A pressure sphere has the advantage of being buoyant, requiring no extra flotation. The use of Benthos 36-cm glass spheres to contain the instrumentation was pioneered for OBS by *Latham et al.* [1978]. *Kasahara et al.* [1979] have also designed an instrument using a Benthos glass sphere. Glass spheres are particularly useful for simpler, less expensive instruments which can be made to fit inside. It is impressive to see them being deployed since they can be handled by two persons (without a crane) and are very easy to deploy from large or small vessels. Care must be exercised with shipboard radio equipment since the glass containers do not isolate against electrical interference, which was a problem during the Rivera Ocean Seismic Experiment (ROSE) for University of Texas, Galveston, scientists. Another problem with using glass spheres is the loss rate, which seems to be at about 10%, presumably due to sphere failure at depth. For an inexpensive recording package, however, the operational advantages of glass spheres are impressive.

TABLE 1. Methods of Data Compression and Expected Improvement Factors

Sample Rate Needed, kb s^{-1}	Method	Improvement Factors
96	Standard (12-bit A-D)	1
64	Logarithmic A-D	1.5
48	Difference coding	2
48	Delta modulation	2
32	Adaptive delta modulation	3
24	Subband coding	10
16	Transform coding	40
8	Adaptive predictive coding	30

Figure 1 shows an OBS using a tube [*Mattaboni and Solomon*, 1977]. It uses a 24.1-cm ID tube with a 2.5-cm wall thickness. The external sensor package will be discussed later. Tubes with 15.24 cm ID (6 in.) are more commonly used in physical oceanographic applications and are also used in OBS capsules. Figure 2 shows a design using multiple tubes of this size [*Prothero*, 1979]. Wires connecting the tubes are routed through a common baseplate. The use of tubes for the pressure case has some advantages over spheres. The tube length is variable so that space can be made for future upgrades without a complete redesign of the package; a sphere is much more difficult to enlarge. Tubes with flat endcaps provide good surfaces for hydrophones and test connectors, and the interior electronics can be removed more easily for checkout. They are also much less expensive than spheres. The sphere cases are more difficult to disassemble, since the hemispheres are heavy and difficult to hold on to. Handles are usually not installed on spheres, to reduce corrosion at the attachment points. Portable shipboard labs have been specially designed to make this less difficult [*Prothero*, 1976]. A spherical design has a major advantage, however: External flotation is not needed, and this will make it easier to avoid vibrational modes which will distort the signal to be measured. Also, larger components such as sensors and recorders will fit into the sphere but may not fit into the smaller tube instruments.

Acoustic Transponders and Communication

For accurate location of capsules and communication of diagnostic information between the deployed OBS and a surface ship, an acoustic communication system is very useful. The use of acoustic communication was pioneered for free-drop capsules by *Snodgrass* [1968]. Since then, they are commonly incorporated in OBS capsules [e.g., *Prothero*, 1974; *Koelsch and Purdy*, 1979]. Acoustic communication allows the location of the instrument to be determined to an accuracy of several meters relative to the ship's position. Inversion techniques for optimally locating an array of instruments relative to a ship receiving satellite navigation information have been developed [see *Creager and Dorman*, 1982]. Absolute instrument locations can be determined to 20–30 m. by this technique. Flexible instrument recovery times can save expensive shiptime, and allow nonfunctioning instruments to be recovered and redeployed. Simple, manually decodable diagnostic codes allow status information such as ground noise level, tape consumption, and number of triggers to be determined before the instrument is left for a long experiment. *Prothero* [1979] also uses the acoustic system to determine in situ OBS clock corections accurate to several miliseconds.

Commercial acoustic systems in use by various groups are manufactured by Sonatech Corp. [*Prothero*, 1979; *Prothero*, 1974], A.M.F. [*Koelsch and Purdy* 1979; *Koelsch et al.*, 1982], Benthos Corp. [*Ambuter and Davis*, 1981], an InterOcean Corp. rebuild [*Moore et al.*, 1981], and are homebuilt [*Tucker*, 1969]. A new, self-contained acoustic release and transponder of extremely small size (12-cm diameter by 51-cm length) was described by H. Murakami [*Naguma et al.*, 1981]. It uses frequency modulation between two carrier frequencies of 11.0 amd 10.5 kHz to encode the commands and has successfully been used in direct distances up to 8 km from the surface ship.

Data Logging Systems

The design of OBS data recording electronics has been dominated by the dynamic range and storage requirements, which are severe for seismic data. A typical earthquake experiment with an OBS might require a bandwidth of 50 Hz and a recording time of 1 month. For digital data, this would require more than 2.5 x 10^8 samples for each component recorded. Analog tape recorders have been built which run very slowly and record for 1 month on large reels [e.g., *Johnson, R. V., et al.*, 1977]. An important limitation of analog recording is the dynamic range, which is less than 40 dB in the direct write mode. Schemes where various gain channels are employed improve the situation, but the fundamental dynamic range problem exists.

Earthquake experiments place the most stringent requirements on dynamic range of the recording system. If magnitude 0 to 6 earthquakes are to be recorded without saturation, a range of more than 6 orders of magnitude must be recorded. However, a particular event can be adequately recorded using just 12 bits (1:4096 resolution) of data as long as the peak signal is onscale. Gain-ranging amplifiers provide a solution to this problem. D. Koelsch (Figure 3) reported on a new ocean bottom hydrophone capsule which implements gain ranging in five 12 dB gain steps [*Koelsch et al.*, 1982]. The block diagram shows that the system includes an RCA COSMAC 1802 microprocessor for system control and a DC-300 cartridge tape recorder with 17.3 Mb (megabytes; 1 byte = 8 bits) of data capacity. This system is capable of sampling to 1500 Hz with a 12-bit A-D converter, and to 8500 Hz with an 8-bit A-D. It stores data in a 53,248-byte semiconductor buffer before it writes it to the tape recorder. Capacity for future expansion is provided by using dual port memory and saving space for an NSC 8000 (low-power Z-80 equivalent) microprocessor. Timing is provided by an oven-controlled crystal oscillator accurate to 1 part in 10^9. A lithium battery pack supplies enough power in the existing pressure case for a 21-day deployment.

This system was designed with the ability to perform high-resolution, high-frequency array studies of shallow structures using controlled sources. Particularly noteworthy is its use of a commercial cartridge recorder. This is a great advantage because the tape recorder is usually one of the components difficult to build and keep running. The only problem with the cartridge recorder is its size, which in the standard configuration will not fit into a 15.24-cm ID pressure tube. Another consideration with a cartridge recorder is that mechanical vibration associated with the high tape speed will most likely shake the seismometer. This means that a semiconductor buffer which can hold the entire event of interest will be necessary, or contamination of the data must be accepted.

Prothero and Schaecher [1981] described modifications to the UCSB microearthquake OBS [*Prothero*, 1979] to optimize it for the recording of teleseisms. A block diagram of the electronics system is shown in Figure 4. Three-component, gimbal-level seismometers are amplified through filters and a gain-ranging amplifier with three 18-dB gain steps. The gain is reduced by a hardware threshold detector and reset to its maximum value by computer command. This enables gain changes to follow the signal or to be left constant throughout the duration of the event. The system is controlled by an IM6100 12-bit microprocessor, which executes the instruction set of the PDP-8 minicomputer. Recording is done on a Braemar cassette recorder with capacity of 1.8 Mb on a C90 cassette. The cassette recorder has the disadvantage of low data capacity, but it is very quiet and does not observably shake the seismometers when it runs. All triggering, gain setting, acoustic diagnostics, and data acquisition are controlled by the microprocessor. Modifications to the original microearthquake instrument to allow for teleseismic recording include adding a third tube, changing the seismometers, amplifiers, anti-alias filters, and some new software. The rather minimal hardware changes needed to produce this significant change in function of the instrument attests to the flexibility of a microprocessor-based data logging system. The entire triggering system (including triggering filters) is implemented in software, so the system is very flexible. The response of the 1-Hz Mark Products L4-C seismometers is boosted at low frequencies using a filter with a gain of 100 higher at 20-s periods than at 1-s periods, so useful response to periods as low as 30 s is achieved. The power consumption is low enough to consider deployments as long as 1 year.

The Intersil IM6100 microprocessor is also used by the group at Scripps Institute of Oceanography [*Moore et al.*, 1981]. Functionally, it is very similar to the unit of *Prothero* [1979] It incorporates three-component, 1-Hz sensors and a hydrophone sensor. A modified Uher tape recorder provides high data capacity and is contained in a spherical pressure container, as shown in Figure 1.

At the July 1982 meeting D. Bibee reported on a new digital instrument using an RCA COSMAC 1802 microprocessor. It has a hydrophone for a sensor and was designed primarily to accurately record the source-time function of large explosive sources used in refraction studies. Digital data are recorded on the same recorder that the Oregon State University group previously used for analog recording [*Johnson, S. H., et al.*, 1977].

C. Young reported on an interesting seismic data recording system [*Young*, 1982]. He designed a seismic data recording system for land deployment that could be constructed for less than $500. He chose a CODEC chip for the A-D, which encodes the input data with an 8-bit logarithmic code. A Motorola 6805 microprocessor is used to control the gain-ranging, triggering, and recording logic. Recording is done on an inexpensive analog recorder. Tests of the data reconstruction algorithm with real data showed that the signal in the time domain could not be distinguished visually from the original signal. When travel time and waveform synthesis are the primary data interpretation technique

Article (cont. on p. 114)

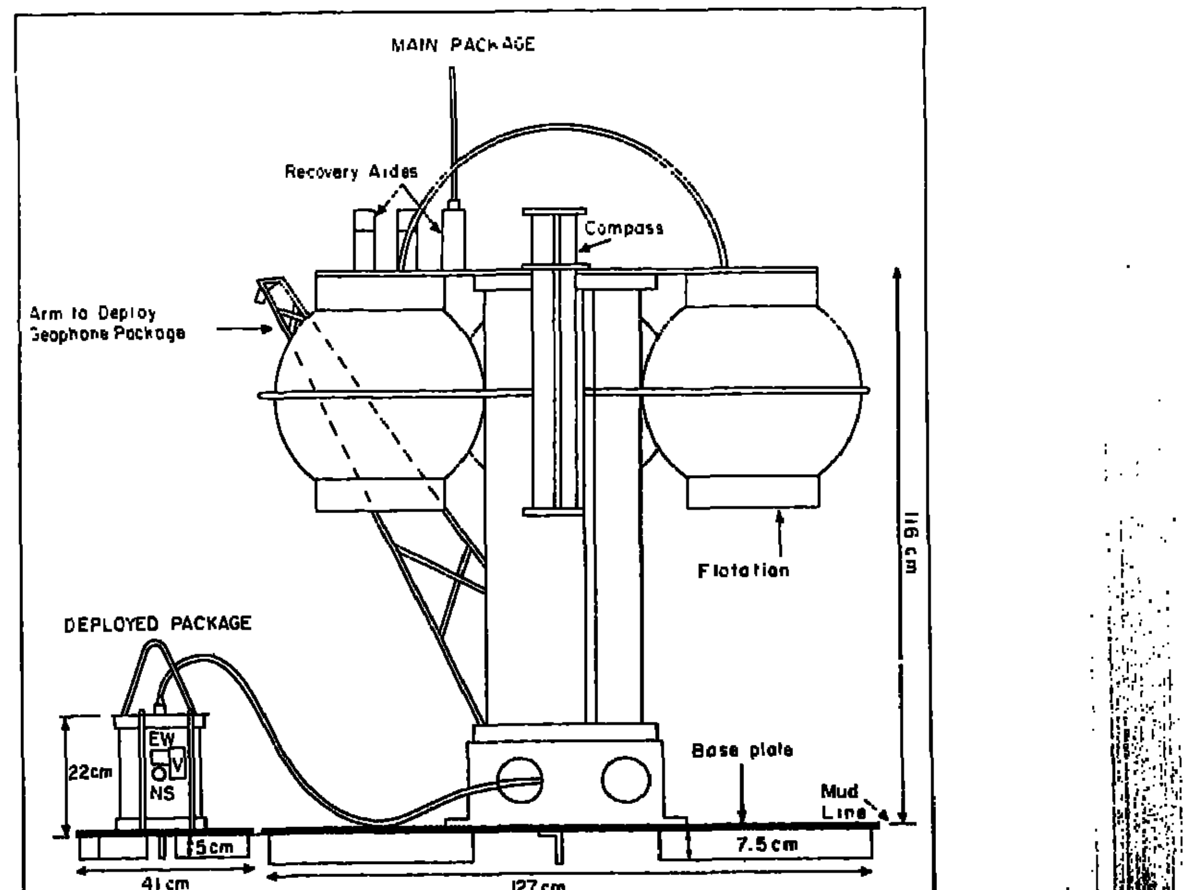


Fig. 1. The Massachusetts Institute of Technology OBS. Note the external sensor package which improves isolation between the main instrument and the sensors [*Mattaboni and Solomon*, 1977].

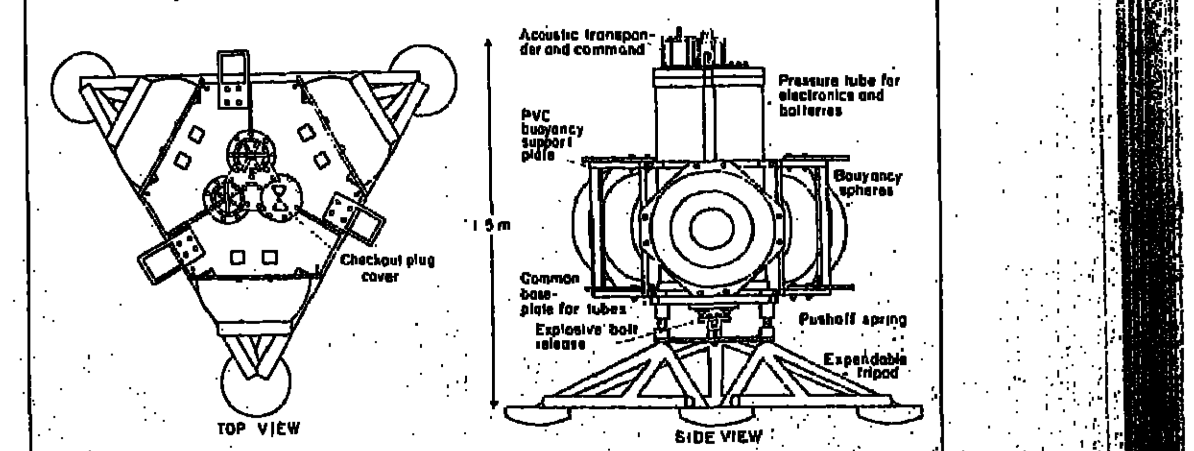


Fig. 2. Diagram of an ocean bottom seismometer from the University of California, Santa Barbara. The machine consists of three tubes connected by a common baseplate and has the capacity to hold enough batteries for a 1-year deployment.

Article (cont. from p. 113)

this system should be quite adequate and offer a good deal of economy. The system was designed for experiments where a rather few recordings with a great number of stations is needed. It has applications for OBS (probably with greater recording capacity) where very inexpensive instruments might be useful.

Tape recorders have been one of the troublesome components of OBS systems. Digital recorders have been used for years by the National Aeronautics and Space Administration for satellite data recording and playback. These are much too expensive for OBS capsules given the funding resources available. OBS engineers have used modified, commercially available analog recorders with good success. *Prothero* [1976] used an unmodified Sony TC800B recorder to record approximately 2.5 Mb of digital data. A similar recorder (Uher 5" reel-to-reel) has been modified by R. Moore of Scripps Institution of Oceanography to record 20 Mb. Unfortunately, the Uher is mechanically noisy and large buffer memories are needed to obtain uncontaminated records. The Sony TC800B was quieter but is no longer available. *Avedik et al.*, [1978] have developed a digital tape recorder capable of recording continuously for 130 hours. This converts to approximately 70 Mb of capacity. *Mattaboni and Solomon* [1977] have constructed a standard format, nine-track recorder which stores 10 Mb. R. Moore has recently completed a prototype of a reel-to-reel recorder with 140 Mb data capacity. Several commercial options are available. *Koelsch* [1982] has successfully incorporated a Quantex cartridge recorder in an OBS package. This stores 17 Mb and uses a 300-ft. (91-m) cartridge tape system. A 67.3-Mb cartridge recorder is manufactured by 3-M Corporation (HCD-75). These recorders all require a good deal of power and start and stop quickly, so they would be expected to cause quite a bit of vibrational noise. Their power can be reduced between recording periods, so even though they are high-power devices the total energy to write a tape may be small. The Quantex requires 0.3 A at 24 volts. The high vibration expected will require large buffers for the data so that the recorder need not be turned on during the event being sampled; new, large-capacity CMOS memory chips make this feasible.

Event Triggering and Data Compression

Since data storage is a major problem for OBS capsules, it is natural to evaluate methods of data compression for this application. The most commonly used method of data compression is event-triggering. This system was first successfully used in OBS capsules by *Prothero* [1974] and *Ambuter and Solomon* [1974]. These instruments used an analog trigger which compares a short-term average (STA) of the background noise to a long-term average (LTA). When the STA/LTA ratio jumps to more than 8, the recorder turns on for 8 seconds. Recording of the event onset is assured by a digital delay line between the recorder and the analog-to-digital converter (A-D). The recorder time is increased (during an event) for each new trigger so that long events are fully recorded. Newer microearthquake trigger algorithms follow approximately the same principle. Event duration is included in the trigger criterion, which can significantly reduce triggering due to impulsive shocks often caused by biological activity in shallow water. Again, the advantage of microprocessor systems is that these trigger computations can be carried out in software, and may be easily changed and optimized.

Teleseismic triggering algorithms for small computers have been reported by *Goforth and Herrin* [1981], *Prothero and Schaecher* [1981], *Evans and Allen* [1983], and *Murdock and Hutt* [1983]. The algorithm developed by Goforth and Herrin uses Walsh transforms [*Shanks*, 1969] to dynamically prewhiten the noise spectrum and examine the frequency content of the signals. These algorithms all use the fact that teleseisms have low-frequency energy, but very little high-frequency energy, while microearthquakes have both low and high frequency energy. The problem is that even though they are implemented on small computers they are still somewhat complex for a full software implementation. Evans and Allen use hardware band-pass filters to determine frequency content of the signal. *Prothero and Schaecher* [1981] reported on a similar triggering algorithm using easily implementable digital filters requiring only shifts (divides by 2). The digital filters are implemented in software and their cutoff frequencies can be easily changed.

Figure 5 shows a block diagram of this system. It is similar in concept to that reported by *Evans and Allen* [1983], but does not have many of the special case conditions optimized for land recording (see also *Prothero*, 1980). The signal is first hipassed to eliminate energy from the increasing low frequency noise of the ocean environment. Then the signal is hipassed by two filters in parallel, with cutoff frequencies of approximately 1 and 4 Hz. The outputs of the two hipass filters are compared and only signals with low-frequency components which are deficient in high-frequency components are considered. This has proven to be extremely efficient at eliminating false triggers. In fact, when the OBS was tested for 1 month in the basement of the geology department at the University of California, Santa Barbara (UCSB) no false triggers were observed, yet all teleseisms which were observed on the SCARLET array stations near UCSB (with sufficient P-wave amplitude) were recorded. During deep-ocean deployments the system proved to be equally robust in discriminating against noise. It is anticipated that increasing the trigger sensitivity will result in increased false triggers, however.

The full review of the possibilities for data compression for seismic recording was presented at the July 1982 meeting by A. Gersho, UCSB department of electrical engineering. He summarized data compression techniques used in speech processing and commented on their possible application to OBS data compression. Some work has also been done on this by *Lee and Yarlagadda* [1982] and *Wood* [1974]. There are three factors to consider in data compression: (1) fidelity, (2) complexity of the algorithm, and (3) compressed bit rate.

The most basic technique of data compression consists of adjusting the sampling to optimize for the expected signals of interest. All OBS groups do this in some form or another. A more generally useful implementation of this technique would add the capability of monitoring the signal spectrum and dynamically adjusting the anti-alias filters and decimation accordingly. Another of the oversampling optimizations in wide use is event triggering. Further compression can be achieved by reducing the number of bits chosen to represent the data. OBS engineers have mostly used 12-bit linear digitization in the past, but an 8-bit logarithmic encoding scheme which shows promise has been studied by *C. Young* [1982]. The second factor, complexity is critical for OBS microprocessor implementation. Some LSI chips have been developed for speech processing, but it remains to be seen whether or not they will be useful for seismic data logging purposes.

Two less common compression schemes of immediate interest are "delta modulation" and "differential coding." Delta modulation is a 1-bit method which samples the data at high speed and produces a "1" if the signal is larger than the last sample, or a "0" if the signal is less than the last sample. "Adaptive delta modulation" increases the step size by 1.5 if two consecutive outputs have the same polarity, and decreases it by 0.6 otherwise; this reduces the overload and granular noise. The fidelity obtainable is determined by the basic sample rate and the quantization interval. Data compression by a factor of 2 is reasonable using this method, and delta modulation A-D devices are commercially available.

Differential coding simply involves storing the difference between the current digitized signal and its last value. When the slew rate (amplitude changes) are low, a great improvement in the number of bits needed for each sample can be made. However, extra bits, needed to indicate the number of bits stored for each sample (for decoding) will reduce the improvement somewhat. This scheme would be straightforward to implement on a microprocessor-based system and the signal fidelity would remain unchanged. Compression by a factor of 2 is estimated for this, but clever coding could probably improve it further.

Other schemes for data compression are subband coding and transform coding. Subband coding consists of band-pass filtering the signal, transforming the filter outputs to low frequencies, then sampling each transformed output at a reduced rate. Transform coding involves transforming the data by some method (e.g., fast Fourier transforms or Walsh transforms), eliminating coefficients with low amplitude, and storing the remainder. This method is discussed in detail for seismic reflection data by *Wood* [1974]. He obtains a data compression of 28:1 with a fidelity of about 85%. This would probably be unacceptable to most OBS users. Table 1 is a summary of the compression ratios expected from the various techniques, as presented by Gersho at the OBS technology conference. These assume that a signal-to-noise ratio of 30 dB is required, but the range of a 12-bit A-D is needed. The actual numbers are based on speech processing needs and would need some modification, as well as testing on actual data, for OBS applications.

It would appear that adaptive delta modulation and difference coding would be the easiest to implement in existing systems. Subband or transform coding may require more computing power than existing microprocessor systems have to spare, so specially dedicated or more powerful processors could be needed. Clearly, there is a large potential payoff in the use of data compression algorithms, and important work remains to be done on this topic.

OBS Coupling and Noise

OBS coupling has received quite a bit of attention recently. OBS intercomparison experiments have shown that identical input signals may be recorded quite differently by different instruments. At the July 1982 conference G. Sutton summarized the results of the Lopez Island intercomparison test [*Sutton et al.*, 1980] and what we now know about OBS coupling. The following list is a summary of possible sources of signal distortion and noise that should be considered in OBS experiment design.

OBS Noise Sources

A. Noise sources with geophysical origin
  1. Microseism amplification
  2. Ocean current-induced noise
B. Signal-induced noise
  1. Distortion from irregular boundaries at sediment-rock interface
  2. Complicated reflections and conversions in the sediment layer
C. Signal distortions
  1. OBS coupling effects, including viscous drag, differential motion between water and instrument, and inertial effects
  2. Water sediment differential motion, which affects the response to horizontal inputs
  3. Rattling due to unstable rocking of instrument on bottom with small scale irregularities
  4. Vertical to horizontal coupling
  5. Tilting induced by horizontal motion
  6. Asymmetries caused by small scale lateral heterogeneities, causing vertical-horizontal coupling

Noise sources with geophysical origin include the microseismic background noise level and ocean current-induced noise. Biological activity and cultural noise can predominate in shallow water and areas of geophysical exploration [*Bradner et al.*, 1980; [illegible], 1982]. Microseism noise is strongly surface weather related [*Latham and* [illegible]; *Nowroozi*, 1968]. In addition, the soft bottom sediments can lead to an amplification of the microseism noise. In spite of this, a number of ocean bottom noise measurements show noise levels comparable to those of coastal land sites [[illegible], 1979; *Prothero and Schaecher*, 1981]. In fact, on hard-rock sites near to ridge crests, the noise at short periods is as low as that on quiet land installations.

A serious potential source of noise is from vibrations induced by bottom currents. Current-induced noise has been observed by a number of researchers, including *Sutton et al.* [1980], *Duennebier et al.* [1981], and *Kasahara et al.* [1980, 1981]. The results of *Kasahara et al.* [1980] suggest that bottom currents frequently exceed 20 cm s^{-1} and can be a major source of noise on an OBS. *Wimbush and Munk* [1970] show current data taken 1.2 m above the seabottom at 32°N, 120°30'W (350 km west of San Diego) that show variations between 5 cm s^{-1} and 0.1 cm s^{-1}, with the predominant frequency being 2 cycles per day. This peak is the "rectified" semidiurnal tide, which is the cause of the dominant variation in current speed at this site. The possibility of rectification must be considered when ground noise is simply correlated with theoretical tidal currents to test for current-induced noise.

The behavior of the current near the bottom is not simple. A boundary layer (called an "Ekman layer") is a transition zone between the current that exists "at great distance" from the boundary and that near the boundary. The mean current velocity vector in this transition zone generally increases with distance from the seabottom and can even reverse direction. It may be laminar or turbulent and for the case of the ocean bottom it is almost always turbulent. For latitudes greater than 30° the critical current speed is 0.1 cm s^{-1} while a typical current speed is 3 cm s^{-1} [*Wimbush and Munk*, 1970]. The dynamics of the boundary layer also depend on the stability of density stratification. Little is known about this on the ocean bottom—not even the sign of the density gradient.

Possible interaction modes are direct forces acting on the OBS by the current, or possibly local ground noise induced by pressure fluctuations acting directly on the bottom by the turbulent boundary layer. The spectrum of the noise which would be generated is unknown but certainly depends on the instrument itself and the current speed. *Kasahara et al.* [1980] have performed experiments to show that the shedding of Karman vortices from the radio beacon antenna causes mechanical oscillations of the OBS at frequencies of 3.2 to 3.7 Hz for current speeds of 18 cm s^{-1} and 30 cm s^{-1}. The amplitude was large enough to saturate the recording system. This effect was severe in this case because the instrument is rather lightweight and the radio beacon antenna, which was mounted vertically at the top of the instrument, forms a resonant mechanical structure. This is also the source of the current noise observed by *Duennebier et al.* [1981] where the radio beacon antenna is high above the main instrument package and the base-to-height ratio is very low. The experience of other investigators in different parts of the ocean has not been so unambiguous. In the Santa Barbara channel and the deep ocean west of Santa Barbara, where current speeds in excess of 10 cm s^{-1} would not be expected, *Prothero* [1981] records noise levels that would not be unreasonable for any coastal land station. The instrument package is 2-m high but has a large base-to-height ratio, and the radio beacon is inverted beneath the deployed instrument, which would reduce the effect of currents.

Several questions arise regarding the current noise problem. It has been shown that reducing the profile of the instrument by lowering the radio beacon antenna will produce improvements when currents are high. Other investigators have no overwhelmingly obvious problems in this regard. Certainly, some of this is due to the different areas of operation, as well as the differences in package configuration. The use of "burp-out" sensors (which are separate from the main instrument package, so have a lower profile) is relevant to this question and will be discussed below in the section on signal distortions.

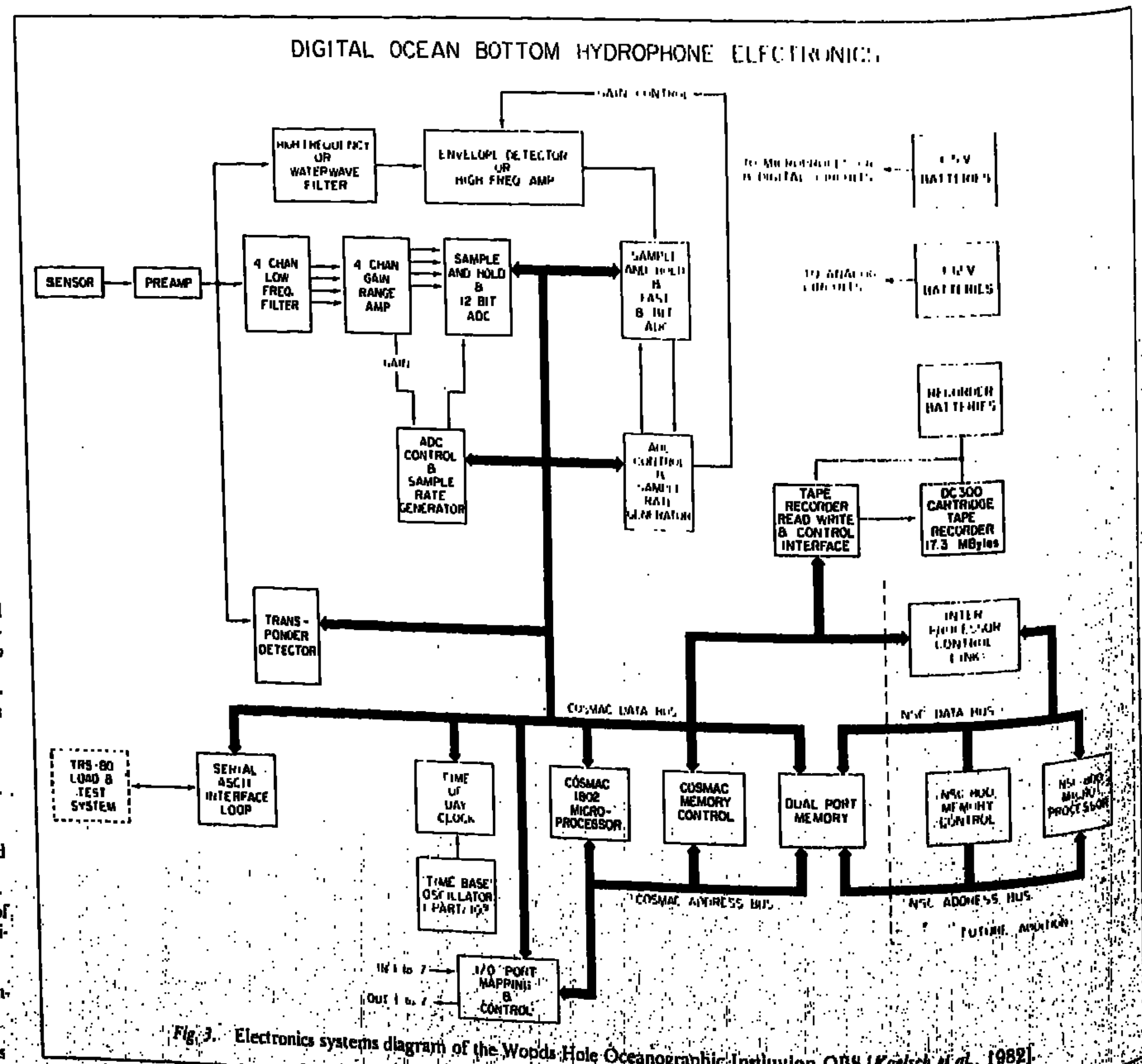


Fig. 3. Electronics systems diagram of the Woods Hole Oceanographic Institution OBS [*Koelsch et al.*, 1982].

Signal-Induced Noise

Signal-induced noise could affect ocean experiments to a greater degree than land experiments because of the water layer and the thick layer of low-velocity sediments often overlying more competent, comparatively high-velocity layers. The velocity contrast at the sediment-rock interface may be quite high, leading to severe distortion from trapped and converted waves. Basement topography could also distort waveform amplitudes, depending on the scale of irregularities relative to the wavelength of the seismic wave.

Signal Distortions

The Lopez Island OBS intercomparison test [*Sutton et al.*, 1980] was conducted to compare the response of existing OBS capsules. What was found was that although some similarities between instruments existed, drastic differences were also apparent. The first-order coupling effect is due to the elasticity of the bottom which the OBS rests upon [*Sutton et al.*, 1980; *Zelikovitz and Prothero*, 1981]. The system may be described as a damped mass-spring system. The mass is the OBS instrument mass plus an added mass caused by the inertia of the water displaced by the OBS motion. The spring constant is determined by the shear modulus of the soil beneath the instrument footpads, and damping is due to the radiation of seismic energy to infinity. Thus, the system will amplify frequencies at the resonant frequency if the damping is low enough. Figure 6 shows a typical coupling response for various coupling parameters typical of existing OBS capsules. Note that a worst-case amplification at the resonant frequency can be as high as 15 dB. A large bearing radius gives rise to a stiff spring and a high coupling resonance (good coupling), while a smaller bearing radius lowers the coupling frequency and increases the need for a coupling correction. A large bearing radius also seems to increase the damping, so that a large bearing radius is preferred.

In addition to the effect of the coupling on the vertical motion, the horizontal signals can cause important and unexpected effects. Several of the OBS packages in the Lopez Island OBS intercomparison test had small anchors relative to the size of the instrument capsule, allowing considerable rocking to occur for horizontal ground motion. Even worse (hindsight tells us), the sensors were mounted at the end of the pressure case, so considerable vertical motion was also induced by the rocking. This led to a good deal of cross-coupling between horizontal and vertical signals. This was clearly indicated by the fact that cross-coupling for each instrument was proportional to its base-to-height ratio. One solution to this is to build the instrument with a high base-to-height ratio and place the sensors along its dynamic center.

A currently fashionable solution to the coupling problem was introduced by the Hawaii Institute of Geophysics group [*Sutton et al.*, 1980, 1981; *Byrne et al.*, 1983; *Duschenes et al.*, 1981]. The sensors, informally called "burp-out" sensors, are able to be deployed separately and at a distance from the main instrument capsule. This technique was very successfully used in ROSE where earthquake data of superb quality were recorded on the MIT instrument [*Trehu*, 1982]. The instrument was deployed on hard bottom where the actual coupling in the vertical direction would be quite good anyway. However, the separated sensor package was well decoupled from internal modes and noise generated by the large recording package and resulted in extremely low cross-coupling distortion.

There are pitfalls, however. It can be seen from Figure 6 that a typical OBS instrument package might have a coupling distortion of a factor of 2 to 3 for frequencies at the coupling resonance. For a factor of 2 coupling distortion, the instrument package will be moving at the equivalent of twice the ground motion (at the coupling resonance), or equal to the ground motion relative to the moving bottom. Thus, on sedimented bottoms where the shear velocities are low, an instrument with this characteristic will be pumping energy into Stonely waves, which will travel to the burp-out sensor and shake it in some unpredictable fashion. Since the burp-out sensors cannot be conveniently separated by much more than a meter from the main package, attenuation due to geometric spreading would be minimal. So, it is necessary that the main instrument package also have good coupling. Indeed, tape recorder vibrations and response to extraneous internal modes of vibration might also transfer to the sensor package (but at reduced amplitudes) under some conditions. From a purely engineering viewpoint the external sensor package poses problems with the reliability of the coupling cable and the possibility that the remote sensor might tangle in the anchor or have difficulty disengaging from the bottom when the OBS is released. In spite of this, the method has important advantages, particularly in high currents, and the data quality has been very good. It would be astute, however, to remain aware of the potential problems that do exist.

Another method of dealing with the coupling problem is by an in situ calibration technique. If the dynamic mass (OBS mass plus added mass from water motion) is constant in frequency and linear over the expected seismic amplitudes, a simple relationship exists between the response of the OBS to ground motion and its response to an internal mechanical shaker; so it is possible to implement an in situ calibration using this reciprocity [*Zelikovitz and Prothero*, 1981]. An important unknown is the behavior of the dynamic mass up to frequencies of seismic interest, a quantity that appears not to have been studied. Eickemeyer and Prothero reported on results in progress of a study of the dynamic mass of two shapes of oscillating bodies: a sphere and a plate. These shapes have dynamic added mass factors (for the laminar flow approximation) of $0.5M_w$ and $4\rho_w R^3/3$, where M_w is the mass of the water displaced by the sphere, ρw is the water density, and R is the radius of the sphere [*Batchelor*, 1967]. In order to test this for sinusoidal motion at seismic frequencies, the shapes were made part of a mass-spring system which could be driven to resonance by a shaking unit. The resonant frequencies between 10 Hz and 30 Hz were compared in and out of water in a tank. The change in resonant frequency is related to the mass change. For a 13-cm diameter sphere and a 25-cm diameter disc the dynamic masses were found to equal the value predicted by laminar flow to within the experimental accuracy of 10%. Further experiments are being performed on larger bodies to check the scaling. If these experiments show similar behavior, accurate in-situ calibration corrections are practical.

0700 An accurate method of seismometer calibration has led *Sauter and Dorman* [1982] to an elegant method of in-situ calibration. It was discovered that the seismometer calibration signal applies enough inertial force on the instrument to cause an observable effect from the coupling to the bottom. This will show up as an additional (small) peak in the transfer function curve. A random telegraph calibration signal is applied. The output signal is correlated with the known input to obtain the seismometer response to a high accuracy, with the coupling response superimposed.

An instrument with the sensor inside must be carefully designed. Of particular importance is the elimination of spurious modes of oscillation. This means that items such as flotation spheres must be connected rigidly to the main instrument package. If they can vibrate within the frequency band of interest, they could distort the response to ground motion. Benthos glass spheres, which are used on a number of OBS, give cause for concern. It is extremely difficult to attach them rigidly to anything since they have flexible polyethylene protection covers through which any attachment must be made. In order to minimize cross-coupling, the base must be wide compared with the height and the sensor should be located near its center line. The base should have a large surface area, particularly when the OBS will be deployed on sedimented areas. However, a single, large-area contact, such as a plate, will be prone to rocking if deployed on harder bottoms with small-scale relief. A tripod anchor guards against this possibility. However, on soft bottoms, a tripod anchor will respond to horizontal signals in an unacceptably asymmetric manner if the coupling is poor. The best solution might be to use a tripod anchor with large area contact pads. An in situ calibration method will give important information on coupling when problems exist.

Article (cont. on p. 116)

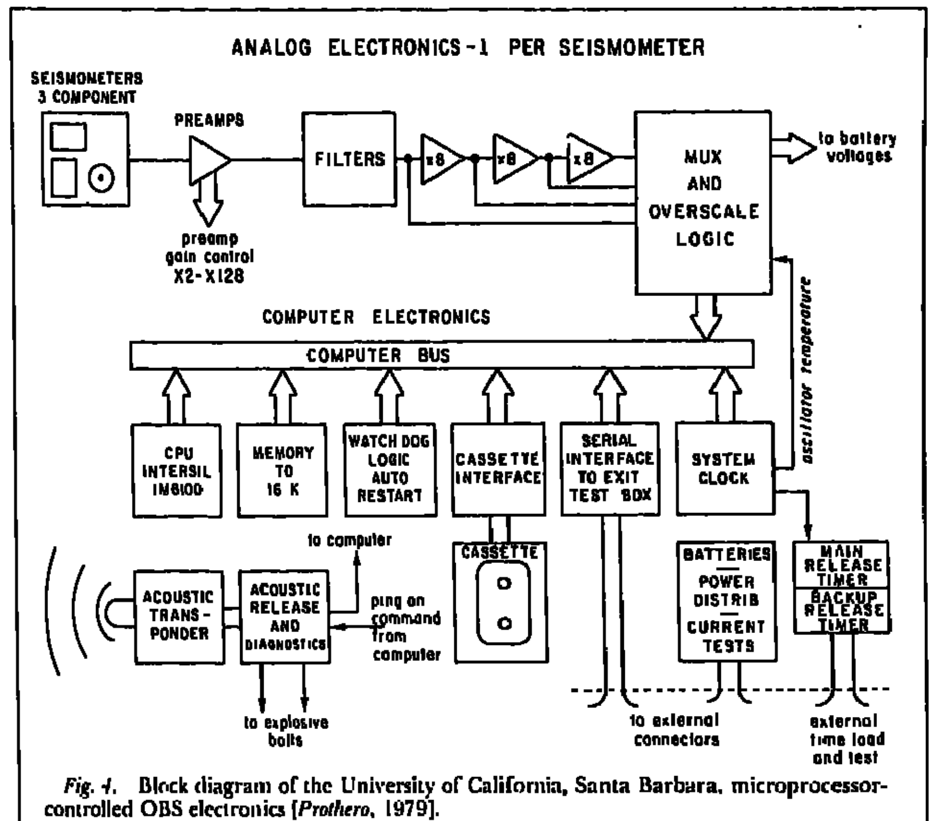


Fig. 4. Block diagram of the University of California, Santa Barbara, microprocessor-controlled OBS electronics [*Prothero*, 1979].

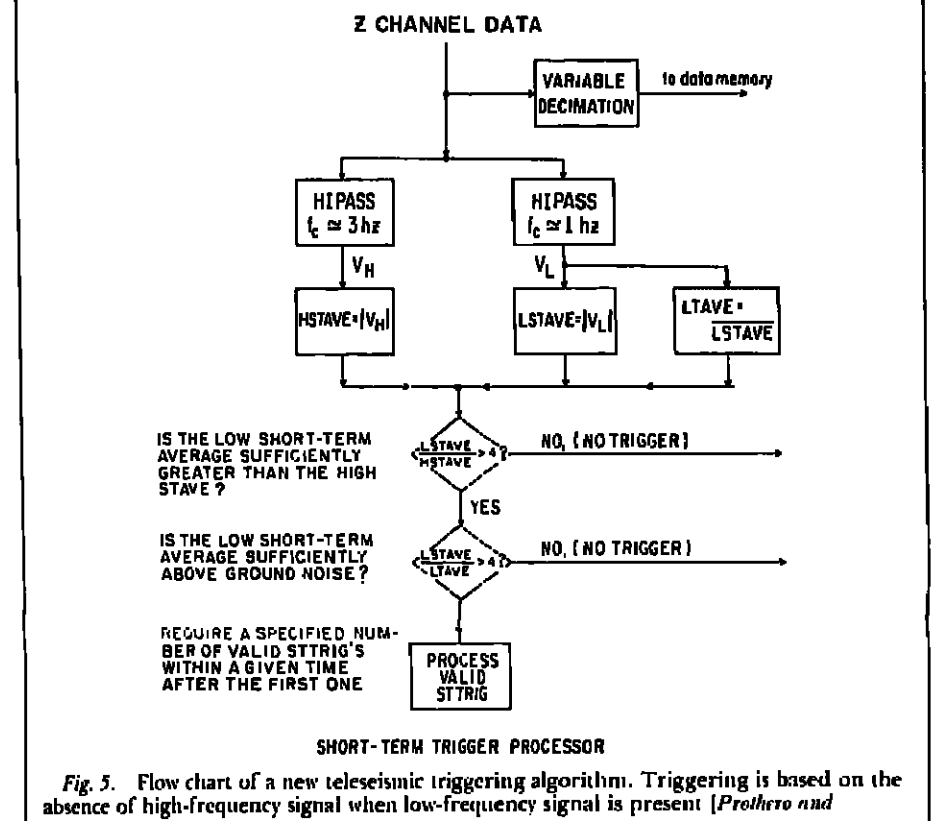


Fig. 5. Flow chart of a new teleseismic triggering algorithm. Triggering is based on the absence of high-frequency signal when low-frequency signal is present [*Prothero and Schaecher*, 1981].

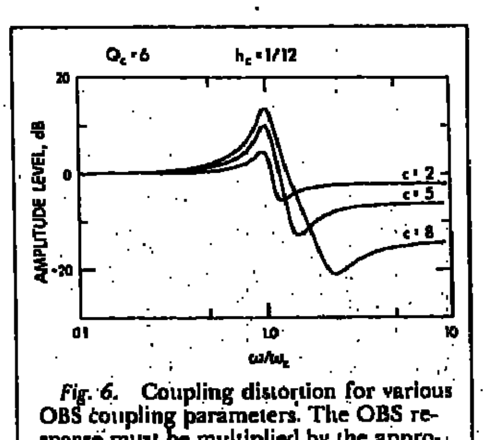


Fig. 6. Coupling distortion for various OBS coupling parameters. The OBS response must be multiplied by the appropriate curve. OBS capsules tested at the Lopez Island OBS intercomparison test behaved according to the full range of curves shown in this figure [*Sutton et al.*, 1980].

EOS
Transactions, American Geophysical Union
The Weekly Newspaper of Geophysics

For speediest treatment of contributions send three copies of the double-spaced manuscript to one of the editors named below and one copy to AGU.

Subscription price to members is included in annual dues ($20 per year). Information on institutional subscriptions is available on request. Second-class postage paid at Washington, D. C., and at additional mailing offices. *Eos, Transactions, American Geophysical Union* (ISSN 0096–3941) is published weekly by

American Geophysical Union
2000 Florida Avenue, N.W.
Washington, DC 20009

Cover. Fountain Square is the historic focal point of Cincinnati, where AGU's 1984 Sping Meeting will be held, May 14–17, 1984. Housing, registration, and travel information and the list of sessions to be held at the meeting begins on p. 122.

Article (cont. from p. 115)

Operations at Sea

Operations at sea are a very important factor in the success of an OBS experiment. An instrument which can be closed up in the land-based laboratory and then quickly checked out prior to deployment without opening it is desirable. When an instrument must be opened, it should be convenient to do so. The design of a checkout system deserves a great deal of attention for more expensive and sophisticated instruments. The ability to playback data at sea is also critical both for instrument checkout and "on-the-spot" planning of further deployments.

Summary

OBS technology has provided quite a number of engineers with some very challenging years. Many of the critical problems regarding coupling and noise have been solved in principle. There remain important design tradeoffs regarding in situ calibration versus well coupled burp-outs, how to get low profile, spheres versus tubes, tape recorder vibrations, internal capsule modes, etc., but most of the critical questions have been at least partially answered. It remains to combine all of the partial answers into one "ideal" OBS, an elusive dream indulged in and argued about by almost everyone involved in the field, particularly when at sea or at OBS technology meetings. However, there will be no "ideal" OBS for all applications. Some investigators will prefer a simple device optimized for artificial source experiments lasting a few days to a week, while others will be looking toward long-term monitoring of natural sources. Individual inventiveness will assure that the "ideal" will remain ever more elusive, even as it is more diligently pursued.

Acknowledgments

The success of OBS work is due to the patience of the funding agencies in the face of slow progress and lost instruments, the investigators who have chosen to put forth the great effort needed to obtain seismic data from the ocean bottom, and most of all the engineers and technicians whose creativity, dedication, and determination are the critical factors in making these oftentimes tricky and temperamental instruments work under the terrible conditions which too commonly befall a seagoing expedition. George Sutton, Sean Solomon, and Don Koelsch gave helpful suggestions concerning this manuscript.

References

Ambuter, B. P., and S. C. Solomon, An event-recording system for monitoring small earthquakes, *Bull. Seismo. Soc. Am., 64*, 1181–1188, 1974.
Ambuter, B. P., and R. Davis, Geophysical-data acquisition in remote environments, *U. S. Geol. Survey Open File Rep. 81–1083*, 1981.
Avedik, F., V. Renard, D. Buisine, and J. Y. Cornic, Ocean bottom refraction seismograph (OBSR), *Mar. Geophys. Res., 3*, 357, 1978.
Batchelor, G. K., *An Introduction to Fluid Dynamics*, Cambridge University Press, New York, 1967.
Brocher, T. M., and B. T. Iwatake, Sources of low-frequency ambient seafloor noise on a continental shelf, *Bull. Seismol. Soc. Am., 71*, 1129–1142, 1982.
Buskirk, R. E., C. Frolich, and G. Latham, Evidence that biological activity affects ocean bottom seismograph recordings (abstract), *Eos Trans. AGU, 61*, 309, 1980.
Byrne, D. A., G. H. Sutton, J. G. Blackinton, and F. K. Duennebier, Isolated sensor ocean bottom seismometer, *Mar. Geophys. Res., 5*, 437–449, 1983.
Creager, K. C., and L. M. Dorman, Location of instruments on the seafloor by joint adjustment of instrument and ship positions, *J. Geophys. Res., 87*, 8379–8388, 1982.
Dorman, L. M., J. A. Orcutt, and T. H. Jordan, Seismic detection and discrimination using ocean-bottom seismographs, *DARPA Annu. Tech. Rep.*, Contract N F0620–79–0019, 1979.
Duennebier, F. K., G. Blackinton, and G. H. Sutton, Current-generated noise recorded on ocean bottom seismometers, *Mar. Geophys. Res., 5*, 109–115, 1981.
Duschenes, J. D., T. W. Barash, P. J. Mattaboni, and S. C. Solomon, On the use of an externally deployed geophone package on an ocean bottom seismometer, *Mar. Geophys. Res., 4*, 437–450, 1981.
Evans, J. R., and S. S. Allen, A teleseism-specific, digital detection algorithm for isolated, short-period seismographs, *Bull. Seis. Soc. Am., 4*, 1173–1180, 1983.
Ewing, M., and A. C. Vine, Deep-sea measurements without wires or cables, *Eos Trans. AGU, 19*, 248–251, 1938.
Goforth, T., and E. Herrin, An automatic seismic signal detection algorithm based on the Walsh transform, *Bull. Seismol. Soc. Am., 71*, 1351–1360, 1981.
Johnson, R. V., C. R. B. Lister, and B. T. R. Lewis, A direct recording ocean bottom seismometer, *Mar. Geophys. Res., 3*, 65–85, 1977.
Johnson, S. H., M. D. Cranford, B. T. Brown, J. E. Bowers, and R. E. McAlister, A free-fall direct-recording ocean bottom seismograph, *Mar. Geophys. Res., 3*, 103, 1977.
Kasahara, J., S. Koresawa, S. Nagumo, T. Daikuhara, T. Hara, and S. Ando, Pop-up OBS (ERI type P-79), *Bull. Earthquake Res. Inst., 54*, 515–530, 1979.
Kasahara, J., S. Nagumo, S. Koresawa, T. Daikuhara, H. Miyata, Experimental results of vortex generation around ocean bottom seismograph due to bottom current, *Bull. Earthquake Res. Inst., 55*, 169–182, 1980.
Kasahara, J., S. Koresawa, and Y. Nishi, Preliminary report for large bottom current at the deep ocean floor inferred from ocean bottom seismic observations, *Bull. Earthquake Res. Inst., Univ. Tokyo, 56*, 207–221, 1981.
Koelsch, D. E., and G. M. Purdy, An ocean bottom hydrophone instrument for seismic refraction experiments in the deep ocean, *Mar. Geophys. Res., 4*, 115, 1979.
Koelsch, D. E., K. R. Peal, and G. M. Purdy, The Woods Hole Oceanographic Institution digital ocean bottom hydrophone instrument, *WHOI Tech. Rep. 82–30*, 1982.
Latham, G., P. Donoho, K. Griffiths, A. Roberts, and A. K. Ibrahim, The Texas ocean-bottom seismograph, *Proc. Annu. Offshore Technol. Conf.*, p. 1467, 1978.
Latham, G. V., and A. A. Nowroozi, Waves, weather and ocean bottom microseisms, *J. Geophys. Res., 73*, 3945, 1968.
Lee, M., and R. Yarlagadda, Reversible Seismic Data Compression, *Proc. IEEE, 70*, 1870–1873, 1982.
Mattaboni, P. J., S. C. Solomon, MITOBS: A seismometer system for ocean-bottom earthquake studies, *Mar. Geophys. Res., 3*, 87–102, 1977.
Moore, R. D., L. Dorman, H. Chin-Yen, and D. L. Berliner, An ocean bottom, microprocessor based seismometer, *Mar. Geophys. Res., 4*, 451–477, 1981.
Murdock, J. N., and C. R. Hutt, A new event detector designed for the seismic research observatory, *U.S. Geol. Surv. Open File Rep.*, 83–785, 1983.
Nagumo, S., J. Kasahara, S. Koresawa, and H. Murakami, Acoustic release ocean-bottom seismometer, *Bull. Earthquake Res. Inst., Univ. Tokyo*, report ERI-AR81, 1981.
Prothero, W., An ocean bottom seismometer capsule, *Bull. Seismol. Soc. Am., 65*, 1251–1262, 1974.
Prothero, W., A digital event-recording ocean bottom seismometer capsule, *Mar. Geophys. Res., 3*, 119–141, 1976.
Prothero, W., An operationally optimized ocean-bottom seismometer capsule, *Phys. Earth Planet. Inter., 18*, 71–77, 1979.
Prothero, W., Earthquake signal processing and logging with a battery powered microcomputer, *Bull. Seismol. Soc. Am., 70*, 2275–2290, 1981.
Prothero, W., and W. Schaecher, An ocean bottom seismometer designed for the recording of teleseisms, *Eos Trans. AGU, 62*, 952, 1981.
Sauter, A. and L. Dorman, Ocean bottom seismometer calibration (abstract), *Eos Trans. AGU, 63*, 1026, 1982.
Shanks, J. L., Computation of the fast Walsh-Fourier transform, *IEEE Trans. Comput., C-18*, 457–459, 1969.
Snodgrass, F. E., Deep-sea instrument capsule, *Science, 162*, 78–87, 1968.
Sutton, G. H., B. T. R. Lewis, J. Ewing, F. K. Duennebier, B. Iwatake, J. D. Tuthill, Lopez Island ocean bottom seismometer intercomparison experiment, *Hawaii Inst. Geophys. Final Rep. 80–4*, 1980.
Sutton, G. H., F. K. Duennebier, and B. Iwatake, Coupling of ocean bottom seismometers to soft bottom, *Mar. Geophys. Res., 5*, 35–51, 1981.
Trehu, A. M., Seismicity and structure of the Orozco transform fault from ocean bottom seismic observations, Ph.D. thesis, *Woods Hole Oceanogr. Inst. Tech. Rep. 82–13*, 1982.
Tucker, M. J., The N.I.O. acoustic transponder, *Nat. Inst. Oceanogr., Internal Rep. A38*, 1969.
Whitmarsh, R. B., and R. C. Lilwall, Ocean-bottom seismographs, Proceedings of NATO Advanced Research Institute on "Structure and Development of the Greenland-Scotland Ridge—new methods and concepts," *NATO Conf. Ser. 4: Marine Sciences*, in press, 1984.
Wimbush, M., and W. Munk, The benthic boundary layer, from *The Sea*, vol. 4, part 1, John Wiley, New York, 1970.
Wood, L. C., Seismic data compression methods, *Geophysics, 39*, 499–525, 1974.
Young, C., Seismic data recorder, M. A. Thesis, Univ. of Calif., Santa Barbara, 83 pp., 1982.
Zelikovitz, S., and W. Prothero, The vertical response of an ocean bottom seismometer-analysis of the Lopez Island vertical transient tests, *Mar. Geophys. Res., 5*, 53–67, 1981.

News

Comet Rendezvous Mission

A National Aeronautics and Space Administration (NASA) advisory team has selected a bright, short-period comet named Kopff as the target for a comet rendezvous/asteroid flyby mission to be launched in 1990. The rendezvous is the third in a series of "core missions"—along with the Venus Radar Mapper and a Mars orbiter—to be proposed following recommendations by the agency's Solar System Exploration Committee (SSEC) two years ago (*Eos*, November 9, 1982, p. 852.) It is planned as a new start in the fiscal year 1987 budget.

The mission will be the first to use the new Mariner Mark II spacecraft derived from earlier vehicles such as Voyager and Viking and intended for deep space reconnaissance. Following a July 1990 space shuttle launch, the spacecraft will fly by and take close looks at the main-belt asteroids Namaqua and Lucia on its way to a rendezvous with Kopff in 1994.

Unlike the international swarm of spacecraft that will make high-speed flybys of Halley's Comet in 1986, the Mariner Mark II craft will stay with Kopff for several years, beginning about 2 years before its close encounter with the sun when the comet is in its inactive state. The spacecraft will orbit Kopff and study it in great detail from ranges of less than 10 km during this period. Then, after the comet begins to heat up and form tails of dust and plasma as it nears the sun, the spacecraft would back off to avoid the surrounding dust while it continued observations.

Kopff was chosen by NASA's Comet Rendezvous Science Working Group, a team of 20 U.S. and European scientists, because of its short orbital period—6.5 years—and because it is particularly active. It is also dustier than most short-period comets.

With the recent inclusion of the Mars Geoscience/Climatology Orbiter as a new start in NASA's budget for fiscal year 1985 (*Eos*, February 14, 1984, p. 49), two of the SSEC core missions to revitalize solar system exploration are already underway. Now that the comet/asteroid mission has been proposed as a 1987 start, a Titan Probe/Radar Mapper is the only one of the committee's "initial sequence" of missions as yet undefined.—*TR*

New Infrared Detectors

Scientists at General Electric's Research and Development Center in Schenectady, N.Y., have developed a new process for manufacturing indium antimonide detectors that will allow them to be used in infrared space satellites for the first time. The process reduces impurities in the detectors and so decreases their "noise" level.

In order to make sensitive infrared observations, detectors using conventional indium antimonide must be operated at temperatures below -181°C, which require liquid nitrogen or liquid helium for cooling. The new detectors will operate effectively at temperatures as high as -151°C, however, and can be maintained indefinitely by satellite refrigeration systems powered by onboard solar cells.

Indium antimonide is the most sensitive and cheapest material available for infrared detectors, but until now its use has been restricted to imaging systems on land or aboard aircraft because of the strict cooling requirements.

USGS Revises Hazards Criteria

New criteria and terms have been adopted by the U.S. Geological Survey (USGS) for issuing formal statements to government officials and the public about geologic hazards such as earthquakes, volcanic eruptions, and landslides.

The new, two-category system comprises a formal notice, called a hazard warning, and an informal notification for forwarding relevant but less critical information to public officials.

USGS Director Dallas L. Peck described the hazard warning as "a formal statement by the director of the USGS that addresses a geological or hydrological condition, process, or potential event that poses a significant threat to public health and safety and for which near-term public response would be expected." For lesser geologic or hydrologic hazards not threatening public safety and for hazards that may require longer-range actions, the USGS will forward information to local and state officials.

There are no specific guidelines for defining when a hazard threatens public safety or poses near-term danger, according to Clement F. Shearer, special assistant in the director's office for natural hazards. Evaluations will be made on a case by case basis, as done under the prior system.

Implemented in 1977, the previous system had three categories of hazard statement: notice of potential hazard, hazard watch, and hazard warning. "A hazard warning tends to create some anxiety within a community," Peck explained. The new system "will help eliminate situations in which USGS statements might cause unwarranted public concern over potential hazards that present low risk to the public. They also will clarify a situation in which we believe a potential hazard may deserve either a near-term or immediate response to save lives or property."

SAR Images Updated

A new camera system using lasers and charge-coupled devices and which can obtain data by radar at any time or under any weather conditions has been designed by the California Institute of Technology as part of a NASA continuing program. The system is intended to improve the imaging functions of synthetic aperture radar (SAR) units. SAR units have been carried on earth-orbiting spacecraft such as the Seasat satellite and the space shuttle Columbia. In the past, imaging was achieved in the craft or a complex process from film. The new system transmits radar imaging data directly to an earth station in real time, the result being an instantaneously synthesized replication.

There are real advantages in being able to collect an entire image in real time. Tedious data collection, analysis, and computer processing are eliminated. The imaging studies of ground and ocean surfaces will be enhanced by being able to adjust the experiment and also to reproduce observations. In addition, the radar beam penetrates into the earth, revealing three-dimensional structure.

The new system has a sophisticated microwave transmitter and an antenna dish designed to receive backscattered radiation. In the new design, the film that records the image is replaced with an acousto-optical device which changes up from the radar and modulates a laser beam. Another acousto-optical crystal is used to transmit the modulated signal onto the charge-coupled device.—*PMB*

More Quakes, Fewer Deaths

The U.S. Geological Survey's (USGS) National Earthquake Information Center has issued a bad news/good news report for 1983. The bad news is that there were more significant earthquakes worldwide than in any year since 1980. The good news is that only 2,322 persons died as the result of those quakes, almost one-third fewer than in 1982 and less than half the 1981 toll.

Significant earthquakes are defined as those of magnitude 6.5 or greater, or those which cause casualties or considerable damage. There were 70 such tremors last year, with 14 classified as "major": magnitude 7.0 to 7.9. "Great quakes" of magnitude 8.0 plus have averaged about one a year in this century, but 1983 was the third year in a row without one.

The biggest jolts of 1983, both of magnitude 7.7, hit Japan on May 26 and the Indian Ocean near the island of Diego Garcia on November 30. Although the Japanese quake was the largest, it resulted in only 104 deaths. By far the deadliest earthquake, resulting in more than half of the year's total fatalities, struck northern Turkey on October 30 with a 6.9-magnitude shock that destroyed 50 villages and left 25,000 persons homeless. Quakes in Guinea on December 22 and in Columbia on March 31 also each claimed hundreds of lives.

Only four of the 70 significant earthquakes occurred in the United States—in southcentral Idaho in October; Coalinga, Calif., in May; Hawaii on November 16; and off the Pacific Ocean off the southern coast of Alaska in February. The Idaho tremor claimed the lives of two children, the first earthquake-related deaths in the U.S. since 1975, and the only American fatalities in the year's quakes. Damage from earthquakes in the United States during 1983 was estimated at over $40 million.

February Streamflow

Streamflows increased dramatically in the Northeast and were well above average in the upper Mississippi River basin and the mountain states during February, according to the regular monthly check of the nation's water resources by the U.S. Geological Survey (USGS).

USGS hydrologists said that prolonged rains in the East, abetted by warmer temperatures that melted accumulated snow and ice, pushed February streams to well above average flows at 90% of the region's 29 key index gaging stations. By contrast, in January, none of these same stations reported above average flows.

Nationwide, 55% (94 stations) of the 172 key index gaging stations reported streamflows that were well above average (within the highest 25% of long-term record), 38% reported average flows (65 stations), and only 7% (13 stations) reported flows that were well below average.

Record or near record high streamflows occurred at 29 index stations in 13 states, including Alaska, the District of Columbia, Florida, Georgia, Iowa (3), Kansas, Michigan (2), Minnesota (5), New York (3), North Dakota, Utah (4), Virginia (2), and Wisconsin (4). Flow of the Cedar River at Cedar Rapids, Iowa, for example, set a new record high flow for February of 28.8 billion liters per day (bld) (7.6 billion gallons a day), the highest February flow in 82 years of record.

The combined average flow of the nation's three major rivers—Mississippi, St. Lawrence and Columbia—reflected the generally above-average February streamflow conditions. Up by 11% over January, the rivers totaled 2570 bld, 4% above the long-term average for February. These three rivers drain more than half of the lower 48 states.

Hydrologist Hai Tang of the USGS National Center in Reston, Va., said that groundwater levels were generally higher than usual for February. New record-highs were recorded at key wells in Iowa and Maine. The key well near Dunning, Neb., reached a level of 0.75 m below the land surface, the highest level in 50 years of record. In Nevada, the Steptoe Valley and Paradise Valley wells were at record-high levels for February. The index well in Las Vegas, Nev., by contrast, set a new record-low level, the lowest in 40 years of record.

Average flows of the so-called "Big Five" rivers were up substantially from January, with only the Columbia River showing a month-to-month decrease. Flows of the "Big Five" for February were as follows: the Mississippi River at Vicksburg, Miss., 1616 bld, 2% below average, but 18% more than the flow in January; the St. Lawrence River near Massena, N.Y., 647 bld, 13% above average, and an increase of 11% from last month; the Ohio River at Louisville, Ky., 428 bld, equal to the long-term average, but nearly twice the flow of January; the Columbia River at The Dalles, Ore., 307 bld, 22% above the long-term average, but down 14% from January; and the Missouri River at Hermann, Mo., 227 bld, above the average February readings, and 84% greater than last month. (map courtesy of USGS.)

Geophysical Events

Volcanic Events

Home Reef (Tonga Is.): Submarine eruption builds islands; tephra to 12 km
Submarine Volcano (Izu Is.): Large area of discolored water; small plumes
Rabaul (New Britain): Seismicity intensifies, tilt rates increase
Manam (Bismarck Sea): Pyroclastic avalanches, scoria flows; eruption columns to 5–8 km; stage-1 alert in force
Langila (New Britain): Activity declines; 1 vulcanian explosion
White Island (New Zealand): Tephra eruption from new vent
Galunggung (Indonesia): Small phreatic explosion
Nyamuragira (Zaire): Lava flows from NW flank
Piton de la Fournaise (Réunion Is.): Tremor declines, then eruption ends
Kilauea (Hawaii): 15th and 16th major phases; lava fountains to 320 m; large tephra fall
Mt. St. Helens (Washington): Lava extrusion stops; deformation and seismicity decline to low levels
Veniaminof (Alaska): Eruption continues; lava fountains and flow
El Chichón (Mexico): No new eruptions; crater lake conditions unchanged
Atmospheric Effects: Lidar still detects aerosols but dawn/twilight colors decrease

Home Reef Volcano, Tonga Islands, *S Pacific (18.99°S, 174.78°W). All times are local (= UT + 13 hours).* An eruption in the vicinity of Home Reef was reported on March 2 at 1107. Intense submarine activity ejected a plume to an altitude estimated by an airline pilot at more than 7.5 km. A surface layer, probably pumice, extended 60 km to the NE and was 20–30 km wide, enveloping Late Island (25–30 km to the NE). Surface discoloration of the sea covered a larger area. Another report at about the same time described a pumice raft of the same dimensions drifting SW. South Pacific Islands Airways (SPIA) reported that the activity was at 19.0°S, 174.80°W.

Gerald Dion piloted Pan American World Airways flight 811 (Honolulu to Auckland) over the area on March 3 at about 0730. From about 18 km upwind, the eruption was visible through broken weather clouds for about 1 minute. A medium-dark reddish-brown eruption column rose from a submarine vent within a horseshoe-shaped island open to the E. The eruption column reached slightly more than 12 km altitude (several hundred meters above the aircraft) where winds carried its top at least 15 km NE.

During the morning of March 4, an SPIA pilot reported that an eruption cloud was still visible, rising high above the sea surface. He saw floating pumice drifting away from the eruption site but no island appeared to have formed. However, before the eruption had ended, by March 5 at 1030, two small islands had formed with a maximum elevation of about 20 m, enclosing a crater about 1500 by 500 m.

Island-forming eruptions of Home Reef Have previously occurred in 1852 and perhaps in 1857.

Information Contacts: Ram Krishna, Director of Meteorology, Fiji Meteorological Service, Private Bag, Nandi Airport, Fiji; John Latter, Geophysics Division, Department of Scientific and Industrial Research, P.O. Box 8005, Wellington, New Zealand; Gerald Dion, Box 417, Kenwood, CA 95452 USA; Meteorological Office, Nukualofa, Tonga; William S. Smith and Tom Kossarias, Federal Aviation Administration, 800 Independence Ave. SW, Washington, DC 20591 USA.

Submarine Volcano, *Izu Islands, Japan (preliminary location 26.07°N, 141.13°E). All times are local (= UT + 10 hours).* On March 7 at 1230, the crew of a Japan Maritime Safety Agency (JMSA) transport plane flying about 130 km N of Iwo Jima observed a fan-shaped zone of discolored sea water that extended about 25 km WSW from a submarine vent. The maximum width of the discolored zone was about 9 km. A helicopter from the base at Iwo Jima flew over the area shortly thereafter and its crew estimated that the extent of the reddish-brown water was roughly as large as Iwo Jima Island (about 5 by 8 km).

The next morning, JMSA personnel observed continuous submarine eruptive activity. Gray or yellowish-brown water was ejected every 10 minutes and waves spread outward from the vents. The sea colors included gray, white, yellowish brown, and reddish brown. The JMSA observers saw neither plumes nor floating ejecta, although small white plumes and rocks or reefs were seen during a flight by the Japan Maritime Self-Defense Force (JMSDF) at about noon the same day. On March 12, personnel aboard a JMSDF patrol plane again saw floating material, and a plume about 100 m above sea level. Only discoloration was found during a JMSA flight March 13. As of the 13th, no new island had been observed at the eruption site.

The activity was located near the site of an eruption reported in 1543 at 26.00°N, 140.77°E.

Information Contact: Office of Volcanic Observation, Japan Meteorological Agency, 1–3-4 Ote-machi, Chiyoda-ku, Tokyo 100, Japan.

Manam Volcano, *off the N coast of Papua New Guinea (4.10°S, 145.06°E). The following is a report from P. Lowenstein.*

"A phase of major eruptive activity commenced at Manam's S crater in mid-February when a series of pyroclastic avalanches was discharged into the SE valley.

"Moderate strombo-vulcanian explosive activity took place at the S crater during the first half of the month, but an intensification was noted from February 12, and on the 17th the first pyroclastic avalanche was discharged. This and the succeeding avalanche on the 21st descended about 4 km from the summit. Smaller avalanches were produced on most days after the 21st, usually terminating about 2 km from the summit.

"Ground and aerial inspections near the end of the month revealed that the numerous avalanches had obliterated most of the pre-existing surface in the upper half of the valley. Trees were flattened and had lost limbs and foliage. Scorching of vegatation had taken place on the 200-m-high valley walls and beyond to distances of 100 m. In addition to these hot pyroclastic avalanches, numerous flows of loose scoria from rapidly accumulated airfall deposits around the vent were also noted. These scoria flows descended into both the SE and SW valleys, terminating within 2 km from the summit.

"Vertical explosion activity at the S crater produced an impressive eruption column which rose to heights of 5–8 km above the vent on several days. Incandescent pyroclasts were ejected to heights of about 700 m, February 17–29. Ashfalls in coastal areas were generally light, although the accumulated thickness may have been up to several centimeters in places, resulting in the loss of branches from some trees.

"The main crater was moderately active throughout the month. Generally, the rate of ash and vapour emission was weak to moderate. Weak, fluctuating glow at night indicated small ejections of incandescent lava within the crater.

"Seismicity showed a strong increase at mid-month corresponding with the intensified visible explosive activity. Between February 14 and 19 the amplitude of B-type events was about 8 times normal. During the remainder of the month a slight reduction to about 5 times normal levels was noted. Daily totals of volcanic earthquakes were steady at about 1700 (February 1–12), rose to 2100 (February 13–25), then returned to 1700.

"Tiltmeter measurements indicated a steady deflationary change of about 2 microradians.

"The stage-1 volcano alert, declared on January 24 in anticipation of increased activity, was maintained in force throughout the month. Warnings were issued to the local population to stay out of the SE and SW valleys."

Information Contact: P. Lowenstein, Principal Government Volcanologist, Rabaul Volcano Observatory, P. O. Box 386, Rabaul, Papua New Guinea.

Earthquakes

Earthquakes

Date	Time (UT)	Magnitude	Latitude	Longitude	Depth of Focus	Region
February 1	1422	5.7M_s	34.68°N	70.54°E	shallow	NE Afghanistan
February 7	2133	7.5M_s	9.91°S	160.49°E	21 km	Solomon Islands
February 17	1719	5.8m_b	36.43°N	70.91°E	213 km	NE Afghanistan

Information Contact: National Earthquake Information Service, U.S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, CO 80225 USA.

Meteoritic Events

Fireballs: SW and Manitoba, Canada; Arizona, Connecticut, Florida, Kansas, Maryland, and Oregon, USA

This is a summary of *SEAN Bulletin*, 9(2), February 29, 1984, a publication of the Smithsonian Institution's Scientific Event Alert Network. The complete Home Reef, Submarine Volcano, and Manam reports are included; the earthquake report is an excerpt. The complete bulletin is available in the microfiche edition of *Eos* as a microfiche supplement or as a paper reprint. For the microfiche, order document E84–003 at $2.50 (U.S.) from AGU Fulfillment, 2000 Florida Avenue, N.W., Washington, DC 20009. For the paper reprint, order *SEAN Bulletin* (giving volume and issue numbers and issue date) through AGU Separates at the above address, the price is $3.50 for one copy of each issue number for those who do not have a deposit account, $2 for those who do; additional copies of each issue number are $1. Subscriptions to *SEAN Bulletin* are available from AGU Fulfillment at the above address; the price is $18 for 12 monthly issues mailed to a U.S. address, $28 if mailed elsewhere, and must be prepaid.

Recent Ph.D.'s

Eos periodically lists information on recently accepted doctoral dissertations in the disciplines of geophysics. Faculty members are invited to submit the following information, on institution letterhead, above the signature of the faculty advisor or department chairman:

(1) the dissertation title,
(2) author's name,
(3) name of the degree-granting department and institution,
(4) faculty advisor,
(5) month and year degree was awarded.

If possible include the current address and telephone number of the degree recipient (this information will not be published).

Dissertations with order numbers, and many of the others listed, are available from University Microfilms International, Dissertation Copies, P.O. Box 1764, Ann Arbor, MI 48106.

Effects of Ice Sheets on Climate Sensitivity, K. P. Bowman, Geophysical Fluid Dynamics Program, Princeton Univ., January 1984.
Evidence for the Nature of the Lower Crust Beneath the Central Colorado Plateau as Derived From Xenoliths in the Buell Park-Green Knobs Diatremes, T. F. O'Brien, Dept. of Geological Sciences, Cornell Univ., August 1983.
Experimental Investigation of Some Physiochemical Controls on Zeolite Formation: Implications for Authigenesis, R. J. Donahoe, Dept. of Geology, Stanford Univ., December 1983.
Generalized Velocity Filters, Shot-Size Calibration in the Frequency Domain, and Seismotectonic Study in the Northeastern United States, Jih-Ping Yang, Dept. of Geological Sciences, Columbia Univ., January 1984.
Geochemical and Experimental Investigations of Andesite-Water Interactions and Their Relationship to Island-arc Geothermal Systems, R. N. Guillemette, Dept. of Geology, Stanford Univ., August 1983.
Geochemistry of Orca Basin Sediments, Der-Duen Shen, Dept. of Oceanography, Texas A&M Univ., May 1983.
Heat Flow Studies in the Gulf of Oman and Western Mediterranean Basins, I. Hutchison, Dept. of Earth Sciences, Univ. of Cambridge, UK, 1983.
Isotopic Evolution of Continent Crust: Granite Petrogenesis and Sediment-Recyling, C. D. Frost, Dept. of Earth Sciences, Univ. of Cambridge, UK, 1983.
Late Cenozoic Geology of the Western Big Bend, San Andreas Fault, T. L. Davis, Dept. of Geological Sciences, Univ. of California at Santa Barbara, 1983.
Late Quaternary Geology of the Upper St. John River Basin, Northern Maine and Adjacent Canada, J. S. Kite, Dept. of Geology and Geophysics, Univ. of Wisconsin–Madison, August 1983.
Rocks From the McDermitt Caldera Complex, Nevada-Oregon, and Adak Island Alaska: Evidence for Crustal Development, W. K. Conrad, Dept. of Geological Sciences, Cornell Univ., August 1983.
Seismic Diffraction Processing Applied to Data From Ashland County, W. E. Doll, Dept. of Geology and Geophysics, Univ. of Wisconsin–Madison, December 1983.
Soil Chronology, Geology, and Neotectonics of the North Central Ventura Basin, California, T. K. Rockwell, Dept. of Geological Sciences, Univ. of California at Santa Barbara, 1984.
Some Boundary Integral Equation Methods and Their Application to Seismic Exploration, G. T. Schuster, Aldridge Lab. of Applied Geophysics, Columbia Univ., January 1984.
Source Apportionment of Particulate Air Pollution in Metropolitan Boston, G. D. Thurston, Dept. of Environmental Health Sciences, Harvard School of Public Health, Harvard Univ., June 1983.
Stratigraphy and Sedimentology of the Upper Proterozoic Kingston Peak Formation, Panamint Range, Eastern California, J. M. G. Miller, Dept. of Geological Sciences, Univ. of California at Santa Barbara, 1983.
Stratigraphy, Petrology and Tectonic Setting of the Alisitos Group, Baja California, Mexico, J. M. Beggs, Dept. of Geological Sciences, Univ. of California at Santa Barbara, 1983.
Upper Llandovery Graptolites and Stratigraphy of the Northern Oslo Region, M. P. A. Howe, Dept. of Earth Sciences, Univ. of Cambridge, UK, 1983.
Use of Photoionization and Other Detectors for Gas Chromatographic Determination of Gaseous Air Pollutants, W. Nutmagul, Laboratory for Atmospheric Research, Washington State Univ., February 1984.
Variations of the Fraser River Plume: Observations and Computer Simulations, L. Royer, Dept. of Oceanography, Univ. of British Columbia, July 1983.
West Spitsbergen Current: Transport, Forcing, and Variability, D. J. Hanzlick, Sch. of Oceanography, Univ. of Washington, December 1983.
Whistler Mode Turbulence at Earth's Bow Shock: Generation via Electron Beams and Ray Path Integrated Amplification, R. L. Tokar, Dept. of Physics and Astronomy, Univ. of Iowa, December 1983.

Books

The Montgolfier Brothers and the Invention of Aviation

Reviewed by Charles B. Moore

Charles C. Gillispie, Princeton University Press, Princeton, N. J., xi + 210 pp., ISBN 0-691-08321-5, 1983, $35.

The first hot air balloon ascension over Paris in September 1783 has been described so many times that it and its passengers—the sheep, the rooster, and the duck—have joined Benjamin Franklin and his kite in the folklore of our culture. Not so well known is the earlier history of ballooning: that the brothers Montgolfier had demonstrated their hot air balloons repeatedly for several months prior to the ascent over Paris; or that the physicist Charles, urged onward and financed by an enthusiast, Barthélemy Faujas de Saint-Fond, launched successfully the first fabric balloon filled with hydrogen over Paris more than 3 weeks prior to the memorable ascent of the sheep, and rooster, and the duck.

For all of its well-documented detail, the book is readable and enjoyable. It is a well-written but complex book in which Professor Gillispie develops a number of subjects to recreate the era in perspective. The origins and the disposition of the Montgolfiers, the industry of the period, the idea of capturing heated air are all reported in detail. The attempts to obtain government funding and the promotional activities in Paris were forerunners of the modern techniques for obtaining support of research activities.

The account of the overly ambitious demonstrations required of the infant art of ballooning is timeless. A similar and predictable sequence developed 160 years or so later, after the end of World War II, when Jean Piccard adapted plastic films to the construction of high altitude balloons. A 20th century entrepreneur with an outlook similar to that of some in the 18th century seized on Piccard's idea and sold the American Navy on an ambitious program in which a cluster of 100 large balloons would be used to carry a gondola with about 100 instruments to an altitude of about 100,000 feet (30 km).

The ascent was scheduled with a fixed date in 1947 before the first useable, plastic balloon was even constructed. The eventual inflation test of the first new balloon was a disaster, worse than any suffered by the Montgolfiers. Under a light wind, the gossamer balloon became a vast, unmanageable spinnaker sail breaking all of the restraining lines and all hopes for the experiment that had been planned. Eventually, techniques to handle the new technology were developed and a more perceptive management rescued the program by the creation of Project Skyhook in the Office of Naval Research. This approach led to a renaissance of scientific ballooning that continues to this day.

The high cost of helium, the inflation gas for these modern charlières, has led to a resurgence of interest in hot air balloons. Over the past 20 years Montgolfier balloons have been improved by Ed Yost and his associates through the use of high-intensity, propane burners and newly designed envelopes of improved fabric so that hot air ballooning has become a major sport worldwide.

While Professor Gillispie's account of early ballooning is fascinating and a paradigm of later human endeavors, even more interesting is the latter part of the book with its history of early attempts to construct internal combustion engines, of Joseph Montgolfier's invention of the hydraulic ram, of the early kinetic energy concepts, of Carnot's antecedents, of bridge design, and many other seminal undertakings. As a student of thunderstorms, I am delighted to learn of Joseph Montgolfier's electrical explanation for the formation of intense rains that even then were observed to fall after nearby lightning (page 141).

I do have one small disagreement with the author's intent, and this has to do with the inclusion of the word "aviation" in the title and in the text. In my view, the Montgolfiers did not "invent aviation" for, in most lexicons available to me, aviation implies "objects, heavier-than-air, flying with wings." This advance was not achieved for more than 100 years after the Montgolfiers. According to the Oxford dictionary, the word "aviation" first appeared in 1887 and it meant "flying in an aeroplane." In 1886, Gaston Tissandier summarized the origins of ballooning thus: "The Montgolfiers created, by experiment, the principle of the balloons; Pilâtre de Rozier, by his ascension [the first manned one, in November 1783], demonstrated the usage of travelling in the air; Charles transformed the new invention and created the aerostatic art." This appraisal, I think, is still appropriate. Certainly the undirectability and the limitations of balloons led later innovators to the invention of aviation. The Montgolfiers and their successors made so many contributions that my cavil here is a minor one. The book would be beyond my reproach if the author had been less ambitious with his claims of the invention of aviation. The index to the book is quite complete and most useful and the book is well bound. This organized and useful compilation of the early scientific contributions by Joseph and Etienne Montgolfier, of Professor J. A. C. Charles, of Meusnier de La Place, of Marc Seguin and of many others is most valuable; it will long be used as a competent guide and source book for the history of the origins of modern science and technology.

Charles B. Moore is with the New Mexico Institute of Mining and Technology, Socorro, NM 87801.

Classified

RATES PER LINE

Positions Available, Services, Supplies, Courses, and Announcements: first insertion $5.00, additional insertions $4.25.

Positions Wanted: first insertion $2.00, additional insertions $1.50

Student Opportunities: first insertion free, additional insertions $2.00.

There are no discounts or commissions on classified ads. Any type style that is not publisher's choice is charged at general advertising rates. *Eos* is published weekly on Tuesday. Ads must be received in writing by Monday, 1 week prior to the date of publication.

Replies to ads with box numbers should be addressed to Box —, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, DC 20009.

For more information, call 202-462-6903 or toll-free 800-424-2488.

POSITIONS AVAILABLE

University of New Mexico/Paleomagnetism. The Department of Geology of The University of New Mexico invites applications for a tenure track full-time position as an Assistant Professor with a specialty in paleomagnetism beginning Fall 1984. The successful candidate will be expected to maintain an active research program and teach at the undergraduate and graduate level. The Department has sixteen full-time faculty, is located in a spectacular natural setting and has excellent analytical facilities.

Applicants should submit a resume, transcripts, and three letters of recommendation to R. Ewing, Department of Geology, Albuquerque, New Mexico 87131. The deadline for applications is April 10, 1984.

The University of New Mexico is an equal opportunity/affirmative action institution.

Research Scientist. Ph.D. in Geology or planetary sciences with five years experience on job or seven years of combined research & teaching experience in planetary and terrestrial volcanic processes. To undertake research in the application of satellite remote sensing data and digital image processing to the interpretation of volcanic terrains. Experience must include combined field and laboratory *multispectral LANDSAT studies of terrestrial volcanic* centers in addition to photogeologic studies of lunar and planetary volcanic structures. $40,280.00/yr., 40-hr. wk. Contact Texas Employment Commission, Houston, Texas, Job Order No. 3384820 or send resume to the Texas Employment Commission, TEC Building, Austin, Texas 78778, Job Order No. 3384820. Ad paid by Equal Employment Opportunity Employer.

Staff Position/Department of Terrestrial Magnetism. The Department of Terrestrial Magnetism of the Carnegie Institution of Washington invites applications for a staff position in geochemistry. Applicants should have a demonstrated ability for active and innovative independent research using trace-element and/or isotopic techniques to investigate the origin and geochemical evolution of the solid earth.

Applicants should send a resume and have three letters of reference forwarded by May 15 to:

Geochemistry Staffing Committee
Department of Terrestrial Magnetism
5241 Broad Branch Road, N.W.
Washington, D.C. 20015

Starting time for the appointment is flexible though a target date of late 1984 is preferred.

Carnegie Institution of Washington is an equal opportunity, affirmative action employer.

Faculty Position in Structural Geology/Tectonics. The Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, has an opening at the Assistant Professor level, in the area of structural geology and tectonics. We will fill this position with either a tenure track or temporary appointment beginning with the Fall 1984 term. For the temporary appointment ranks higher than Assistant could be considered. A Ph.D. is required.

The successful applicant will be expected to teach courses in structural geology, structural analysis, tectonics, and/or other areas of research interest. The tenure track appointee will be expected to develop a vigorous program of sponsored research and to direct graduate student projects.

The MEAS Department currently has 31 full-time faculty, including 12 geologists and geophysicists. Please send complete resume and the names of at least three references to: E.F. Stoddard, Search Committee Chairman, Department of MEAS, NC State University, Raleigh, NC 27695–8208; telephone 919-737-2212. Applications will be considered as received, with a closing date of May 1, 1984.

North Carolina State University is an equal opportunity/affirmative action employer.

The University of Texas at Dallas/Postdoctoral Openings. The University of Texas at Dallas occasionally has postdoctoral openings in the Physics Program. Current research areas include: XUV Lasers and Laser Spectroscopy (C. B. Collins and C. D. Cantrell), Space Plasma Physics (W. B. Hanson and W. J. Heikkila), Space Optics (B. A. Tinsley), Cluster Ion Studies (A. J. Cunningham), Solid State Physics (R. Glosser and R. Chaney). Stipends are competitive. Interested applicants should send vita (indication of sex and ethnicity for Affirmative Action Statistical purposes is requested but not required), and names of three references to: Physics Department, UT-Dallas, P.O. Box 830688, Richardson, TX 75083–0688.

UT-Dallas is an Affirmative Action/Equal Opportunity Employer.

Marine Geochemist (Coastal Processes and Radionuclides)/Marine Sciences Department, University of Connecticut. Nine-month tenure track position as an Assistant or Associate Professor in the Department of Marine Sciences, College of Liberal Arts and Sciences. Ph.D. in earth science (geochemistry), marine geology or oceanography and a strong potential or demonstrated ability to conduct grant-funded research required. The appointee will be expected to teach undergraduate courses in oceanography and advanced courses in his or her specialty, supervise graduate students, and conduct a strong research program in marine geochemistry focusing on the coastal zone with emphasis on radionuclide techniques. Send resume, pertinent publications and names of three (3) references by May 7, 1984 to: W.F. FITZGERALD, Chairman, Search Committee, Marine Sciences Department, College of Liberal Arts & Sciences, THE UNIVERSITY OF CONNECTICUT, Groton, CT 06340.

An equal opportunity/affirmative action employer (Search #4A58).

Computer Programmer/North Carolina State University. Extension Specialist in Biological and Agricultural Engineering. M.S. degree preferred, B.S. required. Position requires strong experience in computer programming and data base management in addition to a working knowledge of statistics. Ability to program in a structured language and experience with SAS preferred. The person selected will interact with environmental scientists to build and analyze a data base on water quality programs nationwide. Salary range $20,000–$25,000 based on experience. Send resume and the names of three references by April 15, 1984, to:

Dr. Michael D. Smolen
National Water Quality Evaluation Project
622 Downtown Blvd.
Raleigh, NC 27603

North Carolina State University is an equal opportunity/affirmative action employer.

FACULTY POSITION

Geological Engineering Program
Department of Civil and Environmental Engineering
Washington State University

The Geological Engineering Program at Washington State University has a tenure-track faculty position at the assistant/associate professor level in the area(s) of geohydrology and/or borehole geophysics. A Ph.D. is required and the ideal candidate will have a background combining both areas.

Geohydrology: A strong background in the geological sciences and a high level of proficiency in numerical modeling is highly desirable. Geophysical exploration background is also desirable.

Geophysics: A strong background in borehole geophysics with interest in geohydrology and evaluation of geotechnical properties of rock is highly desirable.

The successful applicant will teach undergraduate and graduate level courses in geohydrology and/or geophysics and be expected to take over an established research program involving graduate students. Professional registration, or qualifications to *obtain such registration*, is desirable.

Qualified applicants should send a resume, copies of undergraduate and graduate transcripts, and at least three letters of recommendation to Dr. Surinder K. Bhagat, Chairperson, Department of Civil and Environmental Engineering, Washington State University, Pullman, Washington 99164-2910 by April 7, 1984. Washington State University is an equal opportunity/affirmative action employer.

HANFORD

Hanford Operations in Washington

The Rockwell International-managed Hanford Reservation in Richland, Washington is a multi-plant chemical processing and nuclear waste management facility. Join us as we investigate the feasibility of forming a nuclear waste repository within basalt flows underlying the Hanford Reservation. Current opportunities in support of the Basalt Waste Isolation Project include:

Field Hydrologist

To plan, conduct and document borehole hydrologic tests. Requires minimum 7 years experience in field testing with a degree or equivalent combination of education and experience. Knowledge of downhole geophysics and drilling techniques desirable.

Hydrogeologist

Assist in interpreting, integrating and documenting hydrologic data to evaluate the groundwater flow characteristics of a basalt medium. Advanced degree with minimum 6 years experience in field testing and model development required.

Hydrochemist

Plan, coordinate and interpret the results of a variety of field solute transport and geochemical tests. Advanced *degree and a minimum* of 4 years relevant experience in geochemistry and hydrology required.

When you bring your expertise to Rockwell International, you'll receive an outstanding compensation and benefits package, including company-paid medical, dental and life insurance, relocation assistance, plus generous savings and retirement plans. Please forward your resume in confidence to:

B.E. White (B21EOS3/20), Rockwell International, Hanford Operations, P.O. Box 800, Richland, WA 99352. Equal Opportunity Employer M/F. U.S. Citizenship Required.

Rockwell International

...where science gets down to business

CSIRO

RESEARCH SCIENTIST/ SENIOR RESEARCH SCIENTIST

$A24,344–$A35,806
DIVISION OF SOILS
ADELAIDE SA

CSIRO conducts scientific and technological research in laboratories located throughout Australia and employs about 7,500 staff, of whom some 2,900 are professional scientists. The Organization's research activities are grouped into five Institutes: Animal and Food Sciences, Biological-Resources, Energy and Earth Resources, Industrial Technology and Physical Sciences. The CSIRO Division of Soils is a member of the Institute of Biological Resources.

FIELD: Soil physics/hydrology/applied mathematics

GENERAL: The CSIRO Division of Soils conducts research into most aspects of soil science, including the physics, chemistry and biology of soils, and the integrative disciplines of pedology and geomorphology. It also seeks the application of its research in agriculture and in other areas of science and technology. The Division has laboratories in Adelaide, Brisbane, Canberra and Townsville.

DUTIES: The appointee will undertake research as part of a program studying the effect of climate and land management on the entry and redistribution of water in soils. It is anticipated that the principles developed will be used in studies of surface water management and plant/water relations. The appointee's research will be on the applied physics or mathematical aspects of this program. Initially the work will be directed to the study and interpretation of the distribution of deuterium and oxygen-18 in relation to the movement of water in soils and will involve both laboratory *and field studies.*

The appointee will be based at the Division's Adelaide Laboratory which is equipped with a VG602 mass spectrometer, a wide range of equipment for studying the physical and chemical properties of soil and water, and drilling rigs designed for soil sampling. Computing facilities are available on site, and the laboratory is linked to the CSIRO Cyber-76 computer.

QUALIFICATIONS: Applicants should have a PhD degree or equivalent qualifications, supported by established research ability in one or more of the following fields: soil physics or pure physics, physical chemistry, applied mathematics, or hydrology.

TENURE: The appointment is for an indefinite period, following satisfactory completion of a probationary period. Australian Government superannuation benefits are available.

APPLICATIONS: Stating full personal and professional details, the names of at least two scientific referees and quoting reference No A0539, should be directed to:

The Chief
CSIRO Division of Soils
Private Bag No. 2
GLEN OSMOND SA 5064
AUSTRALIA

By April 19, 1984.

CSIRO

RESEARCH SCIENTIST/ SENIOR RESEARCH SCIENTIST

$A24,344–$A35,806
DIVISION OF SOILS
CANBERRA ACT

CSIRO conducts scientific and technological research in laboratories located throughout Australia and employs about 7,500 staff, of whom some 2,900 are professional scientists. The Organization's research activities are grouped into five Institutes: Animal and Food Sciences, Biological Resources, Energy and Earth Resources, Industrial Technology and Physical Sciences. The CSIRO Division of Soils is a member of the Institute of Biological Resources.

FIELD: Soil Physics and Physical Chemistry

GENERAL: The CSIRO Division of Soils studies the physics, chemistry and biology of soil and other porous media, together with the integrative disciplines of pedology and geomorphology. It also seeks the application of its research in agriculture, and other areas of science and technology. The Division has laboratories in Adelaide, Brisbane, Canberra and Townsville.

The Division is strengthening a research program dealing with the physical and mechanical properties of clays, clay soils, and colloidal suspensions. These properties derive from interactions between the mineralogy, the structure and the physical chemistry of the system. The situation is complicated by water and soluble salt movement relative to the colloid.

DUTIES: The appointee will provide theoretical support for this program and in particular would be expected to undertake research in some of the following areas: thermodynamics of clay soils; stress fields in clay soil during water content change and loading and their relationship to shear and consolidation; physical chemistry and mechanics of aqueous solution flow in clay soil in relation to soil structure; mechanical properties, including the rheology and structural stability, of saturated and unsaturated clay soils, and clay suspensions.

QUALIFICATIONS: A PhD degree or equivalent qualifications, with demonstrated research ability and training, for example, in soil physics, soil mechanics, physical chemistry, and/or applied mathematics.

LOCATION: The appointee will be based in Canberra, ACT.

TENURE: The appointment is for an indefinite period, following satisfactory completion of a probationary period. Australian Government superannuation benefits are available.

APPLICATIONS: Stating full personal and professional details, the names of at least two referees and quoting reference No A0525, should be directed to:

The Chief
CSIRO Division of Soils
GPO Box 639
CANBERRA ACT 2601
AUSTRALIA

By April 19, 1984.

CSIRO

RESEARCH FELLOWSHIP

$A24,344–$A35,806
DIVISION OF SOILS
CANBERRA ACT

CSIRO conducts scientific and technological research in laboratories located throughout Australia and employs about 7,500 staff, of whom some 2,900 are professional scientists. The Organization's research activities are grouped into five Institutes: Animal and Food Sciences, Biological Resources, Energy and Earth Resources, Industrial Technology and Physical Sciences. The CSIRO Division of Soils is a member of the Institute of Biological Resources.

FIELD: Soil Management

GENERAL: The CSIRO Division of Soils studies the physics, chemistry and biology of soils and other porous media, together with the integrative disciplines of pedology and geomorphology. It also seeks to establish principles for the application of soil science to agriculture, forestry, hydrology, engineering and conservation. The Division has laboratories in Adelaide, Brisbane, Canberra and Townsville.

The Division proposes to appoint a Research Fellow to participate in "Stragcrop", a collaborative project on soil and other constraints on irrigated crop production within the CSIRO Institute of Biological Resources. The Division of Soils component of the project will focus on structural and mechanical problems presented by soils in which structurally unstable surface horizons overlie dense and impervious clay subsoils. Field work will be concentrated at a site close to the CSIRO Centre for Irrigation Research at Griffith, NSW.

DUTIES: The appointee will study aspects of the nature, origin and consequences of soil structural instability in irrigation agriculture. The study will address the physical-chemistry of these soils in relation to their mechanical and physical properties, and will seek to identify means for their amelioration to ensure long-term crop productivity. The research will involve both laboratory and field studies and will complement that of biologists and applied scientists in Adelaide, Canberra and Griffith.

QUALIFICATIONS: A PhD degree or equivalent qualifications, with demonstrated research ability and training in soil physics, soil mechanics or physical chemistry.

LOCATION: The successful applicant will be based in Canberra, ACT.

TENURE: A fixed term of 5 years. Australian Government Superannuation benefits are available.

APPLICATIONS: Stating full personal and professional details, the names of at least two referees and quoting reference No A0584, should be directed to:

The Chief
CSIRO Division of Soils
GPO Box 639
CANBERRA ACT 2601
AUSTRALIA

By April 19, 1984.

Howard University/Graduate Faculty Position. The Department of Geology/Geography invites applications for a tenure track position in geochemistry at rank of Graduate Associate Professor beginning August 1984. Position involves development of graduate research program at Master's level. Specialization in environmental geochemistry/geochronology/isotope geology desired. Send letter of application, resume and names of three references to: Dr. David Schwartzman, Department of Geology/Geography, Howard University, Washington, DC 20059.

Senior Applications Chemist. Kevex Corporation is seeking an individual with a strong Analytical Chemistry background, in particular in X-ray Fluorescence, for Applications Laboratory.

Three years of experience in Lab or Industrial Analytical Problem solving using XRF is required. Advanced degree in Physical Science or Engineering is preferred. Position requires Applications support to Marketing, Sales and R&D operations. Submit resume to: Mr. Drew Isaacs, Kevex Corporation, 1101 Chess Drive, Foster City, CA 94404.

EOE M/F/H/V.

Air Force Geophysics Laboratory Geophysics Scholar Program (1984–1985). The Air Force Geophysics Laboratory (AFGL) and The Southeastern Center for Electrical Engineering Education (SCEEE) announce that applications are invited for research appointments during the 1984–1985 year in the Geophysics Scholar Program. This program provides research opportunities of 10 to 12 months duration for selected Engineers and Scientists to perform research in residence at the AFGL, Hanscom AFB, near Boston, Massachusetts. Scholars will be selected primarily from such fields as Geophysics, Atmospheric Physics, Meteorology, Ion Chemistry, Applied Science, Mathematical Modeling using Computers, and Engineering.

To be eligible, candidates must have a Ph.D. or equivalent experience in an appropriate technical field. Some appointments may be confirmed prior to August 1984 so early applications are encouraged. All qualified applicants will receive consideration without regard to race, color, religion, sex, or national origin. Application Deadline for September Appointments: August 1, 1984. For further information and application forms contact: SCEEE, 1101 Massachusetts Avenue, St. Cloud, Fl 32769 Telephone: (305) 892-6146.

SCEEE supports Equal Opportunity/Affirmative Action.

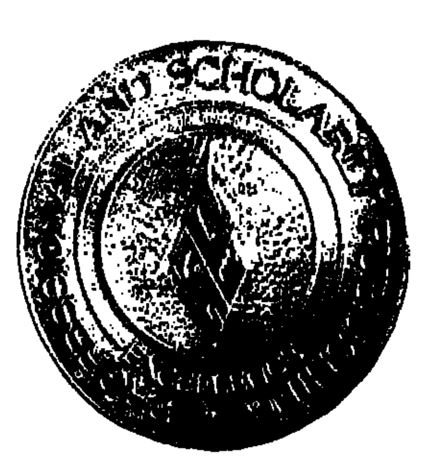
STUDENT OPPORTUNITIES

Research Fellowships at the University of Notre Dame. Fellowships in groundwater physics, groundwater chemistry, anaerobic processes and bioengineering are currently available in the Environmental Engineering Program of the Civil Engineering Department. Successful applicants will be awarded annual stipends of up to $1000/mo. plus full tuition. For additional information, contact Dr. Aaron A. Jennings, Department of Civil Engineering, University of Notre Dame, Notre Dame, IN 46556 (219-239-5846).

SERVICES, SUPPLIES, COURSES, AND ANNOUNCEMENTS

Geodynamics, Inc.: Fluid/Melt Inclusion Determinations. (Heating, Freezing, Bulk, Laser-CO_2/H_2O Individual, Mass. Spec. Volatile I.D.). CARBON & OXYGEN ISOTOPES. BrF_5 available (tremendous discount). **PROMPT SERVICE—BEST PRICES AVAILABLE** GEODYNAMICS, INC., 3518 Tullmore Lane, Tallahassee, FL 32308, 904-893-5699.

AGU



Medallion on the plaque awarded to *Tectonics* by the Association of American Publishers for excellence in journal design and production.

Tectonics Wins AAP Award

AGU's newest journal, *Tectonics*, won the 1983 award for excellence in journal design and production given by the Association of American Publishers, Inc. (AAP), in the eighth annual professional and scholarly publishing awards competition. Edited by John F. Dewey, the bimonthly journal is a joint publication of AGU and the European Geophysical Society. Paul E. Tapponnier is the European editor and B. C. Burchfiel is the North American editor. The journal is now in its third year of publication.

AAP was especially impressed that AGU met its stated objectives in the production and presentation of the journal. Those objectives included increasing the number of words per page, allowing the publication of more science without significantly increasing the size of the journal, and providing higher quality paper to enhance overall quality and reproduction of figures.

"To our knowledge, this is the first time the award has been given to an author-produced journal," said Judy C. Holoviak, AGU director of publications, public information, and marketing. "I'm really pleased that a professionally judged contest can give proper recognition to author-produced copy."

Under the auspices of the professional and scholarly publishing division of AAP, an independent panel of judges from the publishing industry and from the industrial, medical, and scientific community was convened to judge the more than 320 professional and scholarly works that were nominated. The works range across the spectrum of science, technology, business, and humanities nominated for the awards competition. The more than 300 publisher members of the professional and scholarly publishing division of AAP account for the majority of book output and sales of professional and scholarly works in the United States.

Honorable mentions for excellence in journal design and production were awarded to *Winterthur Portfolio*, published by the University of Chicago Press and edited by Ian M. G. Quimby, and to the *Journal of Biomedical Materials Research*, published by John Wiley & Sons and edited by A. Norman Cranin.

The award plaque, displayed at AGU headquarters, states, "1983 Excellence in Journal Design and Production Presented to American Geophysical Union for *Tectonics*, Editor-in-Chief: John F. Dewey, Professional and Scholarly Publishing Division, Association of American Publishers."—*BTR*

AGU Membership Applications

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary section affiliation.

Leonard A. Barrie (A), Kenneth Paul Bowman (A), Donald K. Brundveld (A), Mark Clark, Craig M. DePolo, Robert G. Gibson (G), Boillot G. Gilbert (T), Mark N. Goltz (H), Dennis J. Gregor, Gary B. Griggs (O), Jafar Hadizadeh (S), Rita K. Hayden, Allan D. Hecht (A), William Brent Hemphill, Charles David Hendry (A), George Henry (H).

David Brian Jenkins (A), Kimberly S. Jolitz (SS), Teruo Kanazawa, Benny Kullinger (S), Jonathan W. Lott (O), R. J. Luxmore (H), Gerald L. Madser (G), Clark Markell (H), Mario Martinez, William D. McCoy (H), C. Thomas McElroy (A), Francisco Medina (V), Masanichi Miyamoto (P), Ronald M. Morosky (H), John W. Morse (O).

Brenda L. Norcross (O), Jorgen N. Pihl (S), Filippo Radicati, Michael Retelle (V), Frans J. M. Rietmeijer (A), Ian Rowbottom (H), John Scott (H), Keith Sommer (O), William N. Stammers (H), Marjorie L. Summers (V), Kathy Y. Tonnessen (H), Paul Travis, Parker J. Wigington (H), James C. Witcher (V), Philip C. Woods.

Student Status

Helen J. Anderson (T), Eric Arenberg (V), Shih-Bin Chang (GP), Michael Christie (H), Malcolm E. Cox (V), Isabelle Cozzarelli (H), L. Ford Doherty (O), Robert J. Ellison (T), Jeffrey G. Feehan (T), Benjamin S. Giese, Paul Kevin Gifford (T), Mahboh Hasan (H), Catie Helm, Andrew J. C. Hogg (V).

Dale R. Issler (T), Craig Jarchow (S), Beth Laband (O), J. H. Leete (H), Steven A. Loomis (H), Douglas M. Mach (A), Kevin A. Maher (T), Papu D. Maniar (V), Ritsuko S. Matsumura (S), Gabriele Moehring-Erdmann (T), Jonathan M. Nelson (A), Scott Nutter, Marino Ossos (T), Lee Peyton (H).

Mark Rickertsen (H), Michael E. Roberts (V), Eurdip S. Sahota (T), Suresh Santanam (A), Joachim Schumacher (A), Brad S. Singer (V), Ole Martin Smedstad (O), Joel W. Sparks (V), Scott Starratt (O), Lori Venner (H), Robin J. Weeks (T), Rudolf Widmer (S), Kenneth R. Wilks (T), Jack Wittman (H), David A. Worthington (S), Steven A. Young (T).

Meetings

AGU Spring Meeting

Travel, Housing, and Registration, and Session Summary

The 1984 Spring Meeting of the American Geophysical Union will be held in Cincinnati, Ohio, May 14–17, at the Convention-Exposition Center. The center, located in the heart of the city, is an ideal meeting site; a skywalk system links the Convention-Exposition Center with major downtown hotels, restaurants, and shops. Cincinnati is easily reached by three major highways and the Greater Cincinnati International Airport (only 15 minutes from downtown).

Registration

Everyone who attends the meeting must register. Preregistration received by April 20 saves you time and money. The fee will be refunded to you if AGU receives written notice of cancellation by May 7. Registration rates are as follows:

	Preregistration	After April 20
Member	$70	$85
Student Member*	$30	$45
Retired Senior Member**	$30	$45
Nonmember	$95	$110
Student Nonmember	$40	$55

*Student fee has been rolled back to 1982 rates.
**Age 65 or over and retired from full-time employment.

Registration for 1 day is available at one half the above rates, either in advance or at the meeting. Members of the American Congress on Surveying and Mapping, the American Meteorological Society, the American Society of Photogrammetry, the Canadian Geophysical Union, the European Geophysical Union, and the Union Geofísica Mexicana may register at the AGU member rates.

If you are not a member of AGU and you register at the full meeting rate, the difference between member (or student member) registration and nonmember registration will be applied to AGU dues if a completed membership application is received at AGU by July 9, 1984.

To preregister, fill out the registration form and return it with your payment to AGU by April 20. Preregistrants should pick up their registration material at the registration desk located in the Convention-Exposition Center. Your receipt will be included with your preregistration material. Registration hours are 8 A.M. to 4 P.M., Monday through Thursday. On Sunday, May 13, you may register from 5:30 P.M. to 7:30 P.M.

Hotel Accommodations

Blocks of rooms are being held at the Clarion Hotel (formerly Stouffer's) and at the Netherland Plaza for those attending the Spring Meeting. The Clarion ($55 single, $65 double) is immediately adjacent to the Convention Exposition Center. The Netherland Plaza ($56 single, $66 double) is approximately three blocks from the Center, easily accessible by the skywalk system.

Hotel reservations must be received by April 16, 1984, to be confirmed. **Mail the completed housing form directly to the hotel of your choice. Do not write or telephone AGU for housing reservations.**

Scientific Sessions

The program summary appears later in this issue. The preliminary program with the abstracts will be published in the April 17 issue of *Eos*. The final meeting program, with presentation times, will be distributed at the meeting. Scientific sessions will be held at the Convention–Exposition Center.

Exhibits

Exhibits of instrumentation manufacturers book publishers, government agencies, and other organizations will run from Tuesday, May 15, to Thursday, May 17, 9 A.M. to 5 P.M. daily.

Special Events

An icebreaker party will be held on Monday evening in the Grand Ballroom of the Clarion Hotel, from 5:30 to 7. This will be the opening social event of the meeting.

Awards Ceremony and Reception

All meeting participants are invited to attend this event! The Awards Ceremony will be held in the Hall of Mirrors at the Netherland Plaza Hotel at 6:00 P.M. on Wednesday, May 16. A reception in the Third Floor Foyer will immediately follow the ceremony and offer a time for you to meet, congratulate, and share a glass of wine with those being honored.

President's Dinner

The President's Dinner, held in honor of the medalists, awardees, and Fellows will begin at 8:00 P.M. in the Continental Room of the Netherland Plaza Hotel. Black tie is optional. Dinner tickets are $25 per person. Purchase tickets with your preregistration because only a limited number will be available for sale at the meeting.

Complimentary refreshments will be served Monday through Thursday at the Convention Center, 9:30 A.M. to 10:30 A.M. and 2:30 P.M. to 3:30 P.M.

Program Summary

Union
Approaches to IGBP, Mon PM
Space Research, Tues AM

Atmospheric Sciences
Acid Precipitation, Wed AM
Earth Rotation I, Thurs AM
Upper Atmosphere, Thurs AM
General Meteorology, Thurs PM

Geodesy
Gravity Analysis I, Mon AM
Gravity Analysis I, Mon PM
Precise Positioning: SLR/VLBI, Tues AM
Trends in Geodesy, Tues PM
Geodetic Methods, Wed AM
California Tectonophysics, Wed PM
Geodesy and Tectonophysics, Wed PM
Earth Rotation I, Thurs AM
Earth Rotation II, Thurs PM

Geodynamics
Geodynamics Pgm./CDP, Mon AM
Continental Tectonics I, Mon PM
Gravity Analysis I, Mon PM
Precise Positioning: SLR/VLBI, Tues AM
Crustal Studies, Tues PM
California Tectonics, Wed PM
Geodesy and Tectonophysics, Wed PM
MAGSAT, Wed PM
Earth Rotation I, Thurs AM
Earth Rotation II, Thurs PM
Gravity Analysis II, Thurs AM

Geomagnetism & Paleomagnetism
Paleomagnetism and Rock Magn., Mon AM
General GP, Mon PM
Magnetic Strat. & Time Scales, Tues AM
MAGSAT, Wed PM
SV & Geodynamic Implications, Thurs AM

Hydrology
General Groundwater I, Mon AM
G-W Transport Field Methods, Mon PM
Transport Processes I, Tues AM
Mesoscale Precipitation I, Tues AM
Transport Processes II, Tues PM
Mesoscale Precipitation II, Tues PM
Catchment Geochemistry, Wed AM
General Groundwater II, Wed AM
General Hydrology, Wed PM
Hillslope Hydrology, Thurs AM
Sediment Storage, Thurs PM

Ocean Sciences
Ocean Drilling, Mon PM
Ocean Response to Winds, Mon PM
Physical Oceanography, Tues AM
EM Fields, Tues PM
Gulf Stream, Tues PM
Straits and Sills, Wed AM
Inland Seas, Wed AM
Pelagic Sedimentation, Wed PM
Gulf Of Maine, Wed PM
Marine Chemistry and Geology, Thurs AM
El Niño, Thurs PM

Planetology
Lower Crustal Processes I, Mon AM
Lower Crustal Processes II, Mon PM
Planets and Exospheres, Tues PM
Planetary Posters, Wed AM

Seismology
Shallow Structures, Mon AM
Mantle Convection, Mon AM
Rupture and Prediction, Mon PM
Tomography and 3-D Problems, Tues AM
Theoretical Seismology, Tues PM
No. American Earthquakes, Wed AM
Global, Regional, Volcanic, Wed PM
Solid Earth Posters, Wed PM
Honoring Bill Best I, Thurs AM
Structural Seismology II, Thurs PM
Honoring Bill Best II, Thurs PM

SPR: Aeronomy
Aurora-Airglow, Mon AM
Ionosphere-Irregularities, Mon PM
Upper Atmosphere Waves, Tues PM
Thermosphere-Exosphere, Wed AM
Mid-Atmosphere Transport, Wed PM
Ionospheric Processes, Thurs AM
Upper Atmosphere, Thurs AM

SPR: Cosmic Rays
Solar Flare Particles I, Wed AM
Solar Flare Particles II, Wed PM
Cosmic-Ray Cutoff Rigidities, Thurs PM

SPR: Magnetospheric Physics
Comet/Planet Ionospheres, Mon AM
Ionosphere/Plasmasphere, Mon AM
Project Westford, Mon PM
Auroral Phenomena I, Mon PM
Auroral Phenomena II, Tues PM
Particle Distributions, Tues PM
Numerical Simulations, Tues PM
Jupiter and Saturn, Wed AM
Ionospheric Experiments, Wed AM
Waves/Instabilities I, Wed PM
Reconnection/Pulsations, Thurs AM
Electric Currents/Fields, Thurs AM
Aurora and Substorms, Thurs AM
Distant Magnetotail, Thurs PM
Waves/Instabilities II, Thurs PM

SPR: Solar & Interplanetary Physics
Solar Wind/Comets, Tues PM
Shocks and Foreshocks, Tues PM
Solar Physics, Thurs AM
Upstream Waves/Particles, Thurs PM

Tectonophysics
Mantle Convection, Mon AM
Continental Tectonics I, Tues PM
Mantle Convection and Processes, Mon PM
Ridges and Fracture Zones, Tues AM
Marine Tectonics, Tues PM
Mineral Point Defects, Tues PM
Crustal Structure, Wed AM
Geodesy and Tectonophysics, Wed PM
Solid Earth Posters, Wed PM
Rocks Deformation, Wed PM
California Tectonics, Wed PM
Continental Extension, Thurs AM
Continental Tectonics II, Thurs AM
Continental Tectonics III, Thurs PM

Volcanology, Geochemistry, & Petrology
Mineral Physics I, Mon AM
Lower Crustal Processes I, Mon AM
Lower Crustal Processes II, Mon PM
Mineral Physics II, Mon PM
Metamorphism and Precambrian, Tues AM
Mineral Physics III, Tues AM
Cumulates and Immiscibility, Tues PM
Mineral Point Defects, Tues PM
Isotopic Geochemistry I, Wed AM
Granite Rocks, Wed AM
Volcanic Petrology, Wed AM
Solid Earth Posters, Wed PM
Oceanic Basalts, Thurs AM
Isotopic Geochemistry II, Thurs AM
Mantle, Thurs PM
Experimental Petrology, Thurs PM

AMERICAN GEOPHYSICAL UNION SPRING MEETING
MAY 14–18, 1984
HOUSING REGISTRATION FORM

PLEASE CHECK ACCOMMODATIONS

Check appropriate box and mail this form to preferred hotel

☐ Single (one bed, one person)
☐ Double bed (one bed, two persons)
☐ Twin beds (two beds, two persons)

SUITES UPON REQUEST

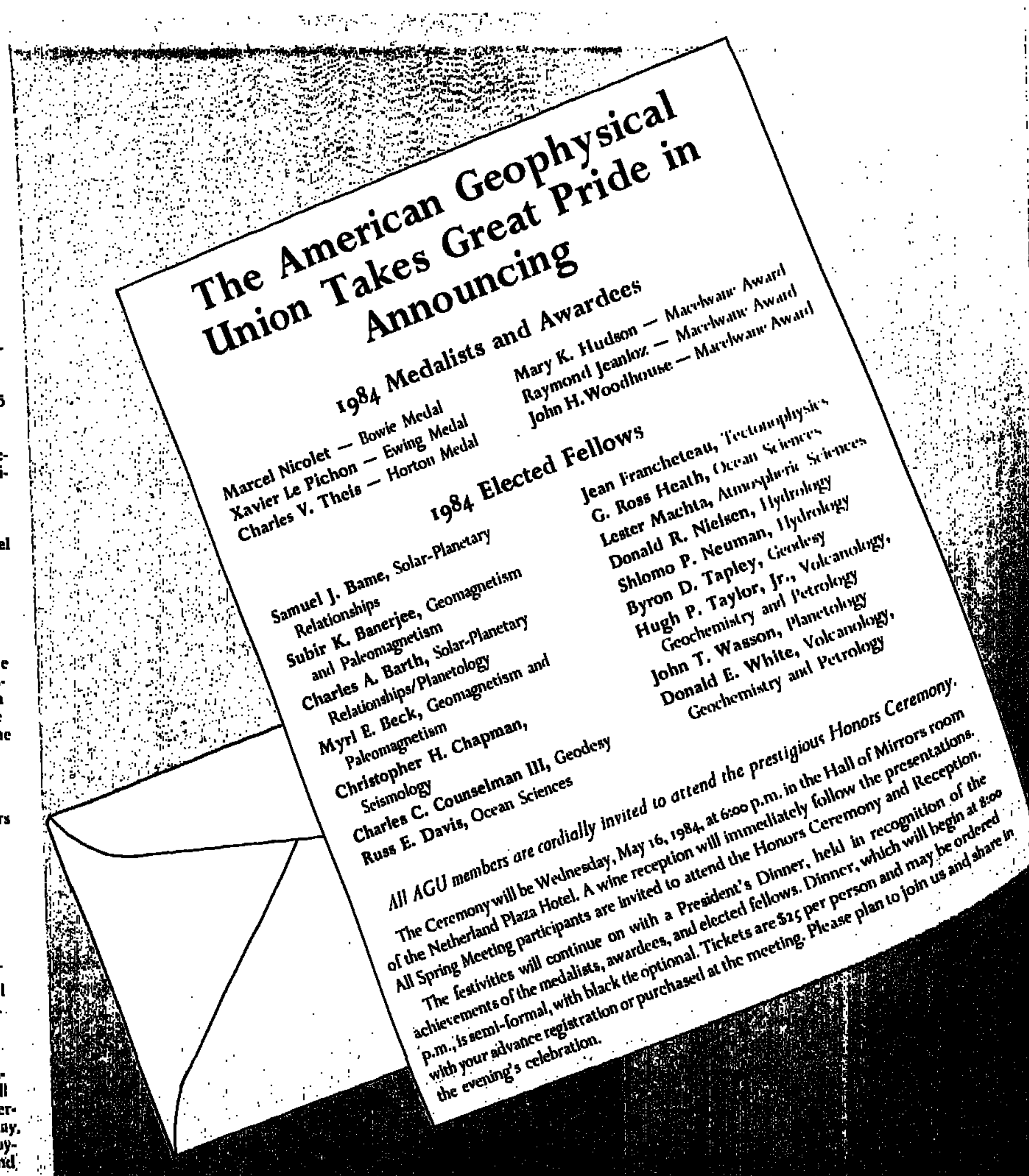
☐ Clarion Hotel
141 West 6th St.
Cincinnati, OH 45202
513-352-2100
$55 Single/$65 Double

☐ Netherland Plaza
35 West Fifth St.
Cincinnati, OH 45202
513-421-9100
$56 Single/$66 Double

Please Note: Reservations must be received by April 16 in order to be confirmed. All reservations received thereafter will be confirmed subject to availability.

Arrival Date ________ AM ☐ PM ☐
Departure Date ________ AM ☐ PM ☐
Name ________
Address ________
City ________ State ________ Zip ________
Company Name ________
Shared with ________
Address ________
City ________ State ________ Zip ________
Company Name ________

IMPORTANT NOTE: Hotel MAY require a deposit or some other form of guaranteed arrival. If so, instructions will be on your confirmation form.



Announcements

TAE Users Conference

May 1–2, 1984 Transportable Applications Executive (TAE) User's Conference, Greenbelt, Md. Sponsor, NASA Goddard Space Flight Center. (TAE Support Office, GSFC Code 933, Greenbelt, MD 20771; tel.: 301-344-6034.)

This public conference will feature discussion and demonstrations of the Transportable Applications Executive (TAE), a portable, standard computer/user interface whic! is now available for general use. The TAE program is a command and menu driven system that processes user input and sends it to an application program. It is used by NASA in large-scale meteorological analysis systems, image processing systems, and data base management systems. It is also used by universities and private industry.

The users conference is being planned TAE users, who will offer live demonstrations of the program and how-to sessions on writing applications with TAE, workstation software development with TAE, porting TAE to UNIX, and many other topics.

China and Global Climate

October 30–November 3, 1984 Symposium on Relationships Between Climate of China and Global Climate—Past, Present, and Future, Peking, China. Sponsors, Academia Sinica, IAMAP, American Meteorological Society. (Jih-Ping Chao, Institute of Atmospheric Physics, Academia Sinica, Beijing, China.)

Deadline for abstracts is May 1, 1984.

The goal of the symposium is to compare climate change in China with that of other regions in the world during the past, present, and future. The physical causes of similarities and differences will be discussed. Among the specific topics to be addressed are climatic fluctuations over the past 2000 years or more, air-sea interactions with particular reference to the west Pacific, land surface-climate interaction, and prediction methods for monthly and seasonal climate variations. The meeting language will be English.

Salt Lakes and Arid Zones

September 24–28, 1984 SLEADS (Salt Lakes, Evaporites, Aeolian Deposits) Workshop on Cenozoic Salt Lakes and Arid Zone Hydrology, Geochemistry, Stratigraphy, and Paleo-environments, Mathoura, New South Wales, Australia. Sponsor, Australian National Univ.. (J. M. Bowler, Dept. of Biogeography and Geomorphology, Research School of Pacific Studies, Australian National Univ., GPO Box 4, Canberra 2601, Australia.)

Registration deadline is May 1.

Contributed papers are invited on the subjects of salt lakes and arid zones, using Australian examples with comparisons from China, Africa, India, and the United States. The conference program will be divided into two general parts: regional, or site specific contributions; and thematic contributions drawing on information from multiple sites.

The meeting will be followed by a 2-to-3

Business Meetings and Section Luncheons

The AGU Council will meet Tuesday, May 15, at 5:30 P.M. The annual business meeting of the Union will follow the Council Meeting. Members are welcome to attend.

All section luncheons will be held at the Clarion Hotel; room locations will be published in the April 17 issue of *Eos*. Please indicate on the registration form which luncheon you plan to attend and include payment.

Monday, May 14

Geomagnetism and Paleomagnetism, $7
Keith Runcorn, University of Newcastle, UK, will speak on "Lunar Magnetism." Sponsor: 2G Enterprises

Planetology/Volcanology, Geochemistry and Petrology, $9.50

Tuesday, May 15

Seismology, $5
Lynn R. Sykes, LDGO, will speak on "Seismological Research and the Nuclear Test Ban: The 25th Year." Sponsors: Kinemetrics, Inc.; Teledyne Industries, Inc.; and W.F. Sprengnether Instruments Co., Inc.

Tectonophysics, $9.50
Irwin I. Shapiro, Harvard Smithsonian Center for Astrophysics, will speak on "Applications of Space Geodesy to Tectonophysics."

Wednesday, May 16

Hydrology, $9.50

Ocean Sciences, $9.50
Paul M. Wolff, NOS/NOAA, will speak on "New Direction for the National Ocean Service."

Solar-Planetary Relationships, $9.50
S. M. Krimigis, APL/JHU, will speak on "Priorities in Solar and Space Physics: Progress on the Current Academy Study."

Thursday, May 17

Atmospheric Sciences, $9.50

Geodesy, $7
Arne Bjerhammar, Visiting Scientist at the National Geodetic Survey, will speak on "Einstein: An Early Surveyor (?)." Sponsor: Bell Aerospace and Textron.

RETURN THIS FORM WITH PAYMENT TO: Meeting Registration
American Geophysical Union
2000 Florida Avenue, N.W.
Washington, DC 20009

OR CALL: Toll Free 800-424-2488 or
Meetings 202-462-6903

PLEASE PRINT CLEARLY

NAME FOR BADGE ________

AFFILIATION ________

MAILING ADDRESS ________

TELEPHONE NO. ________

HOTEL ________

Days you plan to attend:
Please check the appropriate box(es)
☐ Mon ☐ Wed
☐ Tue ☐ Thu

Members of the cooperating societies, listed below, may register at AGU member rates.

Please check appropriate box:
☐ Member AGU ☐ Nonmember
Member cooperating society:
☐ AMS-American Meteorological Society
☐ ASP-American Society of Photogrammetry
☐ ACSM-American Congress on Surveying and Mapping
☐ CGU-Canadian Geophysical Union
☐ EGU-European Geophysical Union
☐ UGM-Union Geofísica Mexicana

Nonmembers
If you register at the full-meeting rate, the difference between member (or student member) registration and nonmember registration will be applied to AGU dues if a completed membership application is received at AGU by July 9, 1984.

Preregistrants
Your receipt will be in your preregistration packet. The registration fee will be refunded if written notice of cancellation is received in the AGU office by May 7. The program and meeting abstracts will appear in the April 17 issue of *Eos*, and will be available at the meeting.

AGU 1984 SPRING MEETING
MAY 14-17
Cincinnati, Ohio
REGISTRATION FORM

Deadline for Receipt of Preregistration April 20, 1984

	More than one day	One day
MEMBER	☐ $70	☐ $35
STUDENT MEMBER*	☐ $30	☐ $15
RETIRED SENIOR MEMBER**	☐ $30	☐ $15
NONMEMBER	☐ $95	☐ $47.50
STUDENT NONMEMBER	☐ $40	☐ $20
PRESIDENT'S DINNER (Wednesday Evening)	☐ $25	

*Student fees have been rolled back to 1982 rates
**65 or over and retired from full-time employment

SECTION LUNCHEONS

Circle section and indicate number of tickets. All lunches begin shortly after noon.

______ Planetology/Volcanology, Geochemistry, and Petrology, Monday, $9.50
______ Geomagnetism and Paleomagnetism, Monday, $7
______ Seismology, Tuesday, $5
______ Tectonophysics, Tuesday, $9.50
______ Solar-Planetary Relationships, Wednesday, $9.50
______ Hydrology, Wednesday, $9.50
______ Ocean Sciences, Wednesday, $9.50
______ Atmospheric Sciences, Thursday, $9.50
______ Geodesy, Thursday, $7

Total Enclosed $ ________
(All orders must be accompanied by payment or credit card information. Make check payable to AGU.)

Charge to: ☐ American Express
☐ VISA
☐ MasterCard

Card Number ________
Master Card Interbank No. ________
Expiration Date ________
Signature ________

Meetings (cont. from p. 123)

day excursion through lakes and dunes of the Murray basin. The workshop proceedings are planned for publication. SLEADS is a multidisciplinary research project directed toward study of climatic history, present and past hydrology, geochemistry, biology, and geomorphic-tectonic evolution of late Cenozoic continental arid and semi-arid environments.

The **Geophysical Year** calendar last appeared in the March 6, 1984, issue.

Meeting Report

Magnetic Reconnection

A Chapman Conference on Magnetic Reconnection was held at the Los Alamos National Laboratory, October 3–7, 1983. More than 125 scientists, from more than a dozen countries, participated in the meeting, where 62 scientific papers were presented and discussed. This report briefly reviews material presented at the conference after first giving some background information on magnetic reconnection.

In many interesting systems of magnetized plasmas, magnetic field lines can be divided into several classes on the basis of their topological properties. One such system is sketched in Figure 1. This represents earth's magnetosphere, enveloped in the flowing solar wind which is threaded by the interplanetary magnetic field (IMF). In this system four classes of field lines are identified: (1) "closed" field lines connected to earth at both ends, (2) "interplanetary" field lines that do not connect to earth at all, (3) "open" field lines connected to earth at one end and to the interplanetary field at the other, and (4) "magnetic loops" that connect neither to earth nor to the interplanetary field. Surfaces called separatrices (heavy lines in Figure 1) separate the regions of different topology (i.e., 2 from 3, 1 from 3, and 1 from 4), and these intersect or close upon themselves along lines called X lines (indicated at A, B, and C in Figure 1).

Figure 1 is adapted from a figure in the classic paper by, *Dungey*, [1961], who suggested that magnetic field lines in the flowing solar wind "reconnect" with magnetic field lines of the earth, in the manner shown, and that this process of "magnetic reconnection" accelerates the particles that cause the auroras. The reconnection process involves transporting magnetic flux across separatrices from one region to another, and this is accomplished at the X lines. For example, an interplanetary field line (region 2), brought to the front of the magnetosphere by the solar wind, meets a closed line (region 1) at A. The two lines break where they touch at the X line and immediately reconnect to create two open field lines (region 3) that connect to the north and south polar caps of earth. Similarly, two open field lines, reconnecting at C, create an interplanetary field line and a closed field line. A closed field line, reconnecting at B, creates a magnetic loop (region 4) and a shorter closed line.

Both the complexity and the importance of this process arise from the fact that in all cases of physical interest, magnetic field lines are closely coupled to the mechanical behavior of plasma, so topological changes of the magnetic field must include transfer of plasma across separatrices as well. In fact, magnetic reconnection has been defined as the process whereby plasma flows across a surface that separates regions continuing topologically different magnetic field lines [*Vasyliunas*, 1975]. Topological changes of field lines thus imply definite patterns of plasma flow. They result, furthermore, in a conversion of magnetic energy to kinetic energy of the plasma.

The study of reconnection had its origin in suggestions by *Giovanelli* [1946, 1947, 1948] and by *Hoyle* [1949] that charged particles responsible for solar flares and the aurora, respectively, could be accelerated at X type magnetic neutral points. Support for these ideas has been found in ever increasing numbers of theoretical and observational studies during the intervening years until, today, it is widely believed that magnetic reconnection indeed does explain the sudden large energy releases that characterize solar flares and intense auroral brightenings called auroral or magnetospheric substorms. Furthermore reconnection has been found to play important roles in several areas of fusion research, and interest in it has arisen in relation to some astrophysical objects.

Despite providing conceptually satisfying explanations for phenomena in a variety of disciplines, the idea of reconnection has faced some skepticism, especially among students of the earth's magnetosphere. Thus, when particularly strong new evidence for reconnection emerged in recent years from satellite observations in the magnetosphere, it seemed appropriate for scientists of various disciplines and interested in reconnection to convene to hear about the new observations and to assess fully our present understanding of the phenomenon. That was the objective of the Los Alamos conference.

The technical program included six topical sessions of invited and contributed papers, one poster session of papers on mixed topics, and a final session on Appraisals, Unanswered Questions, and Future Directions. The six topical sessions treated reconnection theory and modeling and the occurrence of reconnection in the laboratory, in earth's magnetosphere, and in astronomical objects.

Theories and models of reconnection usually consider bodies of plasma that satisfy ideal MHD conditions such that the magnetic field can be considered "frozen" into the plasma, (i.e., moving with it). The actual reconnection of field lines then occurs at a small region of the interface (called the diffusion region) around the X line, where localized breakdown of the frozen field condition occurs. Much discussion at the conference was devoted to examining the extent to which the reconnection process is controlled by external boundary conditions. In one view, favored by Axford, reconnection is controlled by external forces that push differently oriented fields of topologically different regions together and dictate the behavior of the field and plasma around the X line. Models of this process were discussed by Walker and Sato, who refer to it as "driven" reconnection. (This should not be confused with "driven" magnetic substorms, a concept advanced by Akasofu in recent years, in which the reconnection process seems to play no role, or at least not a well-defined one.) In another view, favored, for example, by Schindler, the external effects are considered to push the system to a configuration inherently unstable. Reconnection then is initiated by the instability. In this picture, reconnection plays the decisive role in controlling magnetic topology and in releasing previously stored free energy. Because of its similarity with spontaneous phase transition processes, this picture is often referred to as "spontaneous reconnection." Birn described three-dimensional computer modeling of the magnetotail that portrays such a behavior and that has been highly successful in reproducing magnetic field and flow configurations actually observed during substorms.

Data returned by NASA's ISEE 1 and ISEE 2 satellite pair, launched in 1977, has revolutionized our perception of the process of magnetic reconnection at the magnetopause (e.g., at A in Figure 1) and leave little doubt that reconnection is a significant process for energization of the magnetosphere. Sonnerup summarized the basic aspects of reconnection in the magnetopause setting, including the properties of rotational discontinuities, energization of particles in current layers, and the matter of nonsteady, localized reconnection. Two quite different features in the ISEE data have been interpreted as signatures of magnetopause reconnection, and these have led to the present view that there can be both quasi-steady reconnection and impulsive, small-scale reconnection. Paschmann described the quantitative tests of tangential momentum balance of the plasma and magnetic field across the magnetopause that led to the recognition of quasi-steady state reconnection. Tests of energy balance across the magnetopause were also consistent with the occurrence of reconnection but at a somewhat poorer confidence level. Tracing the magnetic field topology at the magnetopause with energetic particles of magnetospheric origin, as described by Daly, has generally provided consistency checks with the data obtained from momentum balance. The rate and scale size of quasi-steady reconnection, as well as the precise onset conditions, cannot be determined from the ISEE data set. It has been noted, for example, that there have been numerous crossings of the sunward magnetopause when the magnetosheath field was southward (i.e., favorable for magnetopause reconnection as at A in Figure 1), and signatures of quasi-steady reconnection were, nevertheless, not identified.

The impulsive, small-scale type of reconnection was first recognized in a certain repeating pattern of magnetic variations seen in the magnetosheath just outside the magnetopause. The identification of these as instances of transport of magnetic flux (thus named flux transfer events or FTE's) was described by Russell. The interpretation is that spatially and temporally limited reconnection takes place near the sunward equatorial magnetopause and that the connected flux tube is dragged along the magnetopause by the ongoing magnetosheath plasma. Simultaneous ISEE 1 and ISEE 2 measurements of individual FTE's, described by Saunders, revealed that they have diameters of the order of 1 earth radius, the magnetic flux within them is ~5 x 10^6 Wb, and the internal field is twisted, implying field-aligned currents of a few times 10^5 A.. Rijnbeek and Berchem reported that FTE's are seen very frequently (every few minutes) by a satellite located near the sunward magnetopause when the IMF is southward.

Figure 1 shows two X lines in the magnetotail at locations B and C. That at C is sometimes referred to as the "distant neutral line" or the "quiet time neutral line." It is thought to be located ~100 to 200 R_E from earth and to be present most of the time, jetting plasma and closed field lines earthward to maintain the plasma sheet of closed field lines (region 1). The leading substorm theory, *often* referred to as the neutral line model or the reconnection model, holds that at the onset of a substorm's expansive phase (marked by sudden intense brightening of polar auroras) a "near-earth neutral line" or "substorm neutral line" forms at B. This follows a preliminary interval (growth phase) of ~30 to 60 min during which magnetic energy (i.e., magnetic field lines) is being added to the magnetotail by reconnection with the IMF at A (Figure 1), leading to a stronger more radial tail field. Reconnection at B soon (in a few minutes) severs the plasma sheet (the nightside region 1 tailward of ~10 R_E, transforming it into a system of closed loops (i.e., region 4 grows by reconnection until it completely absorbs that portion of region 1 tailward of B). This "plasmoid," completely detached from earth, departs tailward, eventually to join the solar wind. Briefly, the model is characterized by a period (growth phase) of magnetotail energization by interplanetary magnetic field (IMF) reconnection at the magnetopause, followed by a spontaneously beginning period (expansion phase) of "unloading" energy during which the tail energy content decreases. The conference session on reconnection in the magnetotail reviewed the observations around which this model has been built.

Much of the skepticism (mentioned earlier) raised against reconnection by students of the magnetosphere has been directed against the above reconnection model of substorms. Opening the conference session on reconnection in the magnetotail, Nishida critically reviewed the evidence and counterevidence. He concluded that convincing observational bases for tail reconnection exist but emphasized that the physical mechanism for it is not yet fully understood and that it is probably not *the only important* agent of tail plasma dynamics. Confusion and skepticism have arisen when people have tried to explain every dynamical feature as due to reconnection and, failing to do so, have discounted the reconnection model altogether. The evidence for the onset of reconnection at expansive phase onset and the ensuing formation and departure of a plasmoid lies in observations, in the tail, of tailward plasma flow, southward turning of the magnetic field, tailward streaming of energetic electrons, and plasma sheet dropout. Bieber reviewed these observations, and Nishida reported on electric field measurements, made by ISEE 1, that have also been recently added to the overall observation set that supports this picture of plasmoid formation and the neutral line model in general. The stretching and intensity increase of the tail field, which are two of the manifestations of tail energization during the growth phase, were described by Fairfield and D. N. Baker, as were observations indicating the loss of tail energy starting at expansive phase onset. Both speakers also demonstrated that the growth of tail energy (growth phase) starts a few minutes after the IMF turns southward.

There is much observational evidence that energetic (up to ~1 MeV) protons and electrons are generated in the magnetosphere during substorms. They are seen in the magnetotail, and they are "injected" into the inner magnetosphere where they are observed at geosynchronous orbit (r = 6.6 R_E) in conjunction with essentially every substorm. D. N. Baker discussed the energetic ion "drift echoes" observed at 6.6 R_E and the "impulsive bursts" of ions seen in the magnetotail, both phenomena suggesting that the energetic ion generation may be temporally confined to an interval of a few minutes around expansive phase onset. Scholer presented a general review of the extensive observations of energetic ions and electrons in the magnetosphere and noted that there have been comparatively few theoretical studies to explain them. Axford suggested that the particles may be accelerated as the plasma sheet is severed since energetic reconnection may occur very rapidly then and cross-tail potentials as high as ~1 MeV might be expected to exist briefly.

NASA's ISEE 3 satellite made passes through the magnetotail as far as 220 R_E from earth during 1982–1983, and several reports of those observations were presented at the conference. These reports contained dramatic new evidence supporting reconnection models of the magnetosphere in general and of substorms in particular. ISEE 3 found that the characteristic cross-sectional structure of the tail (i.e., north and south lobes, separated by a plasma sheet) was recognizable at all distances examined. The flow of plasma in the plasma sheet was almost always tailward and fast beyond ~100 R_E. Scholer and Daly reported that the plasma sheet also contains tailward streaming energetic electrons and ions and that these actually extend above and below the plasma sheet. Cowley showed that all these features are consistent with an open magnetosphere with reconnection occurring at a neutral line earthward of ISEE 3. Gosling reported that the lobe plasma density is often quite different on opposite sides of the plasma sheet and found that these differences showed a dependence on the IMF y component that is consistent with reconnection of the IMF with earth's field near the subsolar magnetopause. D. N. Baker reported increases of the tail diameter at ISEE 3 concurrent with growth phase signatures at geosynchronous orbit and with southward IMF, supporting the picture of tail energization before substorm expansion phases. Hones, Siscoe, and Scholer reported the occurrence of fast tailward moving plasma structures which they identified as plasmoids (i.e., severed plasma sheet sectors) reaching ISEE 3 about 30 min after expansion phase onset at earth (a delay appropriate for the earth-ISEE distance and the 500-1000 km/s flow speed measured in the passing plasmoids).

It is reasonable to expect that magnetic reconnection occurs in other magnetospheres as well as that of earth. Indeed, Behannon and Nishida reported observations of Jovian magnetotail fields and plasmas that can be interpreted as resulting from reconnection in Jupiter's magnetosphere. Niedner discussed comet tail disconnection events (DE's) that have been ascribed to magnetic reconnection at the comet's head when the polarity of the field draping the comet is reversed at IMF sector boundaries. A few examples have been found of discontinuities in comet tail structure that may be due to tail reconnection, similar to the substorm process at earth.

Priest reported that our understanding of the sun's atmosphere has changed dramatically over the past 10 years. Our new view of the sun is dominated by the magnetic field and its relation with the plasma atmosphere in which magnetic reconnection plays a prime role. For example, the solar corona may be heated by turbulent reconnection, and reconnection may play several roles in solar flares. Parker stated that a universal feature of magnetized plasmas is its activity (i.e., plasma turbulence and waves, shocks, superheated gases, and the production of fast particles) which occurs whenever and wherever a magnetic field in a tenuous plasma is subject to externally imposed strains. He also proposed that magnetic reconnection may be the central cause of the activity.

In the laboratory, several axisymmetric toroidal magnetic confinement experiments are presently being studied for controlled fusion. Magnetic reconnection plays a role in at least four of these. The tokamaks is presently the leading contender for development into a fusion power reactor, and in it the role of reconnection is detrimental to plasma confinement. Paré discussed reconnection in tokamak and demonstrated its occurrence in the ISX-B device at the Oak Ridge National Laboratory.

In the reversed-field pinch (RFP) experiment, both toroidal and poloidal magnetic fields are externally applied and are of comparable intensity, resulting in a very highly sheared field unlike that of the tokamak where the toroidal field (aligned the long way around the torus) everywhere dominates the poloidal field (aligned the short way around). D. A. Baker reported that the Los Alamos ZT-40M experiment has maintained discharges at constant current and reversed field for 10 ms (much longer than predicted by calculations) possibly by energy transfer from the poloidal field to the toroidal field by steady state reconnection of the mean fields.

The Field Reversed Configuration (FRC) and the spheromak were discussed by Milroy and by Hammer, respectively. These devices are members of the "Compact Torus" family of magnetic structures characterized by a set of closed, nested flux surfaces but without any coils, transformer cores, etc., protruding through the hole in the torus. Their magnetic configurations are shown in Figure 2. The formation of both involves magnetic reconnection. Spheromaks have been formed successfully in several different ways. In each case, during a "preformation stage," poloidal field lines are wrapped around (or penetrate) solid bodies. During formation, plasma is created, and the toroidal component of the field is introduced. Magnetic forces cause the flux surfaces to distort and eventually reconnect to form the desired set of closed, nested surfaces sketched at the top of Figure 2. FRC's are formed in a field-reversed θ-pinch as follows: (1) an initial reverse bias field is frozen into a cold pre-ionized plasma; (2) the current in the θ-pinch coil is quickly reversed, producing a large forward bias field, which causes the plasma to implode radially; (3) the oppositely directed field lines reconnect near the θ-pinch ends forming a closed field configuration such as is sketched at the bottom of Figure 2.

In summary, the conference exposed many interested scientists to discussions of present thinking about magnetic reconnection and to descriptions of the latest developments concerning reconnection in space and laboratory plasmas. Most of the formal presentations as well as the discussion of them by the participants will apear appear in AGU the *Geophysical Monograph Series*, vol. 30, *Magnetic Reconnection in Space and Laboratory Plasmas*, to be available at the 1984 AGU Spring Meeting in Cincinnati.

Cosponsors of the conference, along with the American Geophysical Union and Los Alamos National Laboratory, were the U.S. Department of Energy, the Institute of Geophysics and Planetary Physics of the University of California, NASA, and the National Science Foundation.

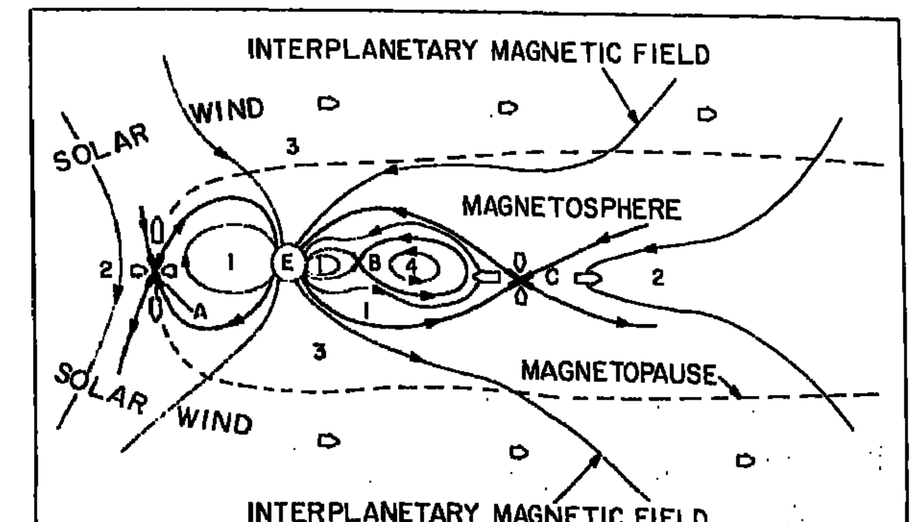


Fig. 1. A sketch of the solar wind-magnetosphere plasma system. Black lines are magnetic field lines with black arrows indicating their direction. White arrows indicate plasma bulk flow. The dashed line is the magnetopause, the boundary between the solar wind-dominated regime and the earth-dominated regime. The drawing is not to scale. Actual distances are earth (E) to A ≈10 earth radii (R_E) (1 R_E ≈ 6370 km); E to B ≈15 R_E; E to C ≈100 R_E; magnetotail diameter ~40 R_E.

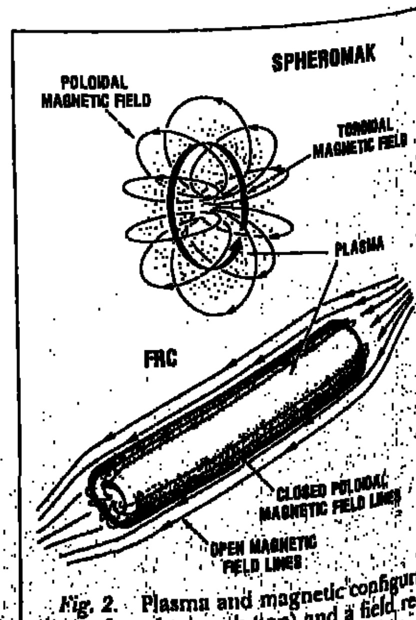


Fig. 2. Plasma and magnetic configurations of a spheromak (top) and a field reversed configuration (bottom).

References

Dungey, J. W., Interplanetary magnetic field and the auroral zones, *Phys. Rev. Lett.*, *6*, 47, 1961.

Giovanelli, R. G., A theory of chromospheric flares, *Nature*, *158*, 81, 1946.

Giovanelli, R. G., Magnetic and electric phenomena in the sun's atmosphere associated with sunspots, *Mon. Not. R. Aston. Soc.*, *107*, 338, 1947.

Giovanelli, R. G., Chromospheric flares, *Mon. Not. R. Astron. Soc.*, *108*, 163, 1948.

Hoyle, F., *Some Recent Researches in Solar Physics*, Cambridge University Press, New York, 1949.

Vasyliunas, V. M., Theoretical models of magnetic field line merging, 1, *Rev. Geophys. Space Phys.*, *13*, 303, 1975.

This meeting report was contributed by Edward W. Hones, Jr., *University of California, Los Alamos National Laboratory, Los Alamos, NM 87545.*

GAP

Separates

To Order: The order number can be found at the end of each abstract; use all digits when ordering. Only papers with order numbers are available from AGU. *Cost:* $3.50 for the first article and $1.00 for each additional article in the same order. Payment must accompany order. Deposit accounts available.

Send your order to:
American Geophysical Union
2000 Florida Avenue, N.W.
Washington, D.C. 20009

Aeronomy

0410 Absorption and Scattering of Radiation
PHOTODISSOCIATION OF $^{16}O^{18}O$ IN THE ATMOSPHERE
[illegible]
J. Geophys. Res., D, Paper 4D0403

0430 Aeronomy (Composition)
AN INTERCOMPARISON OF SAGE AND SBUV OZONE OBSERVATIONS FOR MARCH AND APRIL, 1979
[illegible]

Electromagnetics

0780 Scattering
A TIME-DOMAIN ENERGY THEOREM FOR SCATTERING OF PLANE ELECTROMAGNETIC WAVES
[illegible]

Exploration Geophysics

0910 Computer applications
A METHOD OF EDITING TIME SERIES OBSERVATIONS
[illegible]

0920 Magnetic and electrical methods
OFFSHORE ELECTRICAL EXPLORATION OF SEDIMENTARY BASINS: THE EFFECTS OF ANISOTROPY IN HORIZONTALLY ISOTROPIC, LAYERED MEDIA
[illegible]
GEOPHYSICS, VOL. 49, NO. 5

0930 Seismic methods
ACCURACY OF FINITE-DIFFERENCE AND FINITE-ELEMENT MODELING OF THE SCALAR AND ELASTIC WAVE EQUATIONS
Kurt J. Marfurt
[illegible]
GEOPHYSICS, VOL. 49, NO. 5

0930 Seismic methods
A CASE STUDY OF STRATIGRAPHIC INTERPRETATION USING SHEAR AND COMPRESSIONAL SEISMIC DATA
[illegible]

Geomagnetism and Paleomagnetism

Meteorology

Hydrology

Mineralogy, Petrology, and Crystal Chemistry

Geochemistry

Geodesy and Gravity

Oceanography

Particles and Fields— Interplanetary Space

Particles and Fields— Ionosphere

Journal of Geophysical Research

differential Doppler data with the relative motion term removed are integrated to obtain a representation of the electron density variation along the satellite path. Well-known large-scale features such as the equatorial geomagnetic anomaly and day/night ionization level differences are clearly observed in the integrated data. The larger crest of the morning geomagnetic anomaly is seen to occur in the southern (winter) hemisphere in agreement with previous observations. In addition, a sharp peak in the electron density at the day-to-night transition point is observed in two consecutive revolutions. This effect may be due to the previously postulated atmospheric shock wave generated by supersonic motion of the terminator. (Low-Low Doppler Tracking, Bistatic Satellite Sounding of Ionosphere).
Rad. Sci., Paper 4S0386

5545 Ionospheric disturbances
CHEMISTRY AND DYNAMICS OF SF_6 INJECTIONS INTO THE F-REGION
P. A. Bernhardt (Atmospheric Sciences Group, Los Alamos National Laboratory, Los Alamos, NM 87545)
The chemistry of SF_6 vapor reacting in the F-region is critically examined. The SF_6 molecule dissociatively attaches an electron producing the SF_5^- ion. Reaction between an ambient O^+ ion and the SF_5^- yields mutual neutralization. During the neutralization process, an electronically excited oxygen atom, $O(^1D)$, may be produced which will subsequently emit a 630.0 nm photon. A release of 20 kg of SF_6 into an ambient O^+ ion concentration of 10^5 cm^{-3} at 300 km altitude is considered. The 630.0 nm airglow intensity may increase following the release. The negative ion plasma is shown to be marginally unstable to a gradient drift instability.
J. Geophys. Res., A, Paper 4A0407

5545 Ionospheric Disturbances
THE DISTRIBUTION OF TOPSIDE SPREAD-F IN SITU MEASUREMENTS BY DMSP-F2 AND F4
E.R. Young (Regis College Research Center, Weston, MA, 02193)
W.J. Burke, F.J. Rich and R.C. Sagalyn, Air Force Geophysics Laboratory, Space Physics Division, Hanscom AFB, MA 01731
On the basis of 331 equatorial passes of DMSP at 840 km, we have determined that two distinct types of topside ion depletions occur in the evening sector during equinoctial periods. Firstly, during the early evening (18.9 LT) a smooth type of depletion occurs with over 80% probability of observation per pass. This feature is aligned parallel to the magnetic equator and is probably related to the equatorial fountain effect and general F-region dynamics. Secondly, we have seen irregular depletions later in the evening (19.6h – 21.9h) which are the topside signatures of Spread-F. Their total probability of occurrence per pass increases from ~ 60% at 21.9h. A statistical study of the entire data set has shown that spread-F depletions occur only when the topside ion density surpasses a seasonally controlled threshold. Therefore, longitudinal and local time variations of topside ion density are reflected in similar variations in the occurrence probability of spread-F as reported both here and earlier. A detection model including orbit-feature intersection geometry, the above mentioned threshold, and Poisson statistics has been empirically verified. (Equatorial spread F, equatorial ionosphere, ionospheric disturbances).
J. Geophys. Res., A, Paper 4A0315

5560 Particle Precipitation
INTENSE FLUXES OF LOW ENERGY ELECTRONS AT GEOMAGNETIC LATITUDES ABOVE 85°
David A. Hardy (Space Physics Division, Air Force Geophysics Laboratory, Hanscom AFB, Massachusetts 01731)
A systematic survey was performed to determine the frequency of occurrence of intense fluxes of electrons above the level of the polar rain at geomagnetic latitudes > 85° and their relationship to the orientation of the interplanetary magnetic field, the density and velocity of the solar wind and geomagnetic activity. These intense fluxes we identify as the "polar showers" and "polar squalls" reported by Winningham and Heikkila (1974). For the study 452 orbits of data from the SSJ/3 sensor on the DMSP F2 satellite were used. The orbits selected satisfied the criteria that the satellite attained a geomagnetic latitude ≥ 85° during the orbit and that Interplanetary Magnetic Field (IMF) and solar wind data were available both for the hour in which the satellite passed over the northern hemisphere and the previous hour. The key result of the study is that in 90% of the cases studied an electron flux exceeding the level of the polar rain was found in both hemispheres at geomagnetic latitudes > 85° and that such occurrences are dependent predominantly if not exclusively on the B_z component of the IMF being positive. Unlike visible polar cap arcs, a positive value of the IMF B_z component appears to be both a necessary and sufficient condition for the occurrence of such fluxes above 85° geomagnetic latitude. Occurrence is independent of the IMF B_x and B_y component. The occurrence is strongly skewed toward Kp = 0 but an occurrence exceeding 30% is found up to a Kp = 4.

quasilinear mechanisms in which the initial density gradient is modified by a finite amplitude wave spectrum. Application is made to plasma density fluctuations in the auroral ionosphere but the results are also applicable to plasma jet and striation formation in artificially produced ionospheric plasma clouds. (plasma macroinstabilities, high latitude ionosphere).
J. Geophys. Res., A, Paper 4A0390

MEASUREMENTS OF E-REGION IONIZATION AND CONDUCTIVITY PRODUCED BY SOLAR ILLUMINATION AT HIGH LATITUDES
R. M. Robinson (SRI International, Radio Physics Laboratory, Menlo Park, California, 94025), R. R. Vondrak
Electron density measurements made by the Chatanika radar during times when auroral particle precipitation was absent have been used to determine the variation of E-region ionization and height-integrated ionospheric conductivity as a function of solar zenith angle and solar flux. From the Chatanika radar data taken over an entire solar cycle, we have derived the electron density as a function of altitude between 90 and 250 km for five solar zenith angles between 45° and 85° and for four different levels of solar flux. From 16 to 40 profiles were averaged together to determine the mean values; typically the standard deviations were less than 25 percent of the mean. The height-integrated conductivities computed from these profiles increase by about a factor of two between the lowest and highest levels of solar flux. The solar contribution to the Hall and Pedersen conductances, Σ_H and Σ_P, is well represented by $\Sigma_H = 1.5 (S_a \cos\chi)^{0.5} = 1.7 \Sigma_P$, where χ is the solar zenith angle and S_a is the 10.7 cm solar flux. In order to determine the total conductance when other ionization sources are present, the altitude-dependent production rate is required. This was computed from the data using an altitude-dependent model for the effective recombination coefficient. (Conductivity, photoionization)
J. Geophys. Res., A, Paper 4A0302

Particles and Fields— Magnetosphere

5715 Electric fields
A STATISTICAL STUDY OF DAYSIDE MAGNETOSPHERIC ELECTRIC FIELD FLUCTUATIONS WITH PERIODS BETWEEN 150 AND 600 SEC.
H. Junginger (Max-Planck-Institut für extraterrestrische Physik, 8046 Garching, Federal Republic of Germany), G. Geiger, G. Haerendel, F. Melzner, E. Amata and H. Iligel.
186 days of electric field data from the GEOS-2 electron beam experiment have been used to study magnetospheric fluctuations at geostationary orbit with periods between 150 and 600 sec. While fluctuations are nearly always present in the electric field data from the dayside magnetosphere with typical amplitudes between .2 and .5 mV/m it is often hard to find well defined concurrent pulsations in the GEOS-2 magnetic field data. Most events occur near noon and have the same characteristics: They are toroidal and nearly linearly polarized, the sense of polarization as well as the orientation angles of the polarization ellipses change sign near noon, the instantaneous frequency of the fluctuations is correlated with the instantaneous electron density, in a given sector of the magnetosphere the sense of polarization depends on the frequency. There is strong evidence that these fluctuations are fundamental mode eigenoscillations of field lines in the vicinity of the spacecraft which are generated in the inhomogeneous plasma of the magnetosphere by some kind of solar wind driven surface waves at the magnetopause or at the low-latitude boundary layer. (Geomagnetic micropulsations, electric fields, Alfvén waves).
J. Geophys. Res., A, Paper 4A0408

5725 Interactions between magnetosphere and cosmic rays
ON THE ACCELERATION OF ENERGETIC IONS IN JUPITER'S MAGNETOSPHERE
D. D. Barbosa (Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, CA 90024), A. Eviatar, G. L. Siscoe
A theoretical model and analysis of the acceleration of high-energy ~ MeV/nuc ions in Jupiter's magnetosphere is presented. All measurements conducted in this energy range have consistently pointed to the probable occurrence of local non-adiabatic acceleration above that obtainable by radial diffusion alone. We consider first the creation of fast 75 km/s neutral sulfur and oxygen atoms in the Io torus by charge exchange. This process will eject upwards of 2×10^{28} neutrals per second which are recaptured in the magnetosphere by subsequent electron impact and charge exchange with the ambient plasma outside the torus as well as by solar UV photoionization. All processes together lead to an injection rate of greater than 4×10^{25} heavy ions recaptured per second with a gyrospeed comparable to the local plasma flow speed. We show that subsequent adiabatic radial diffusion cannot produce the observed spectrum of high energies required by observations. We then consider the stochastic acceleration of this seed population by magnetohydrodynamic waves. It is demonstrated how the properties of the observed particle spectrum are related to those of the power spectrum of MHD fluctuations measured by the magnetometer. (Jupiter, magnetosphere, ion acceleration).
J. Geophys. Res., A, Paper 4A0265

5736 Magnetic tail
CORRELATED DYNAMICAL CHANGES IN THE NEAR-EARTH AND DISTANT MAGNETOTAIL REGIONS: ISEE-3
D. N. Baker (University of California, Los Alamos National Laboratory, Los Alamos, NM 87545), S. J. Bame, R. D. Belian, W. C. Feldman, J. T. Gosling, P. R. Higbie, E. W. Hones, Jr., D. J. McComas, and R. D. Zwickl
During October 1982 and January-March 1983, ISEE-3 made its first traversals of the distant (r = 60–220 R_E) geomagnetic tail. Throughout this period the Los Alamos ISEE-3 plasma electron instrument detected the tailward magnetosheath, magnetopause, plasma sheet, and tail lobes. For the entire tail traversal period nearly continuous concurrent data were available from Los Alamos Charged-Particle Analyzer (CPA) instruments on-board the spacecraft 1977-007, 1981-025, and 1982-019 at geostationary orbit (6.6 R_E). Using these geostationary orbit data in the local midnight sector numerous substorm particle injection events were detected, allowing substorm onset determinations to accuracies of a few minutes. Remarkably high degrees of correlation between near-earth substorm events and ISEE-3 transitions from one magnetotail plasma regime to another were often found throughout the tail crossing. Particularly notable were periods of "taillike" magnetic field stretching at 6.6 R_E (substorm growth phases) and diametrical expansions of the distant tail seen by ISEE-3. Similarly, substorm expansion onsets seen at 6.6 R_E were followed by rapid apparent contractions of the translunar tail which took ISEE-3 into magnetosheath and/or boundary layer plasmas. At ISEE-3 distances beyond ~ 200 R_E it is commonly observed that substorm particle injection events at 6.6 R_E precede the occurrence of strong tailward plasma flow by ~25 ±5 min. These results suggest a close relationship between processes in the near-earth plasma sheet and the distant tail during substorms, with particular support for the flaring tail model of the substorm growth phase and for substorm initiation in the near-earth magnetotail region. (Substorms, tail energy storage, magnetotail dynamics).
J. Geophys. Res., A, Paper 4A0299

5755 Plasma Instabilities
A COMPUTER SIMULATION STUDY OF HOOK-INDUCED ELECTROSTATIC BURSTS OBSERVED IN THE MAGNETOSPHERE BY THE ISEE SATELLITE
H. Matsumoto (Radio Atmospheric Science Center, Kyoto University, Uji, Kyoto 611, Japan), M. Ohashi, and Y. Omura
Observations from the ISEE satellite have recently revealed interesting electrostatic bursts which are apparently hook-induced emissions stimulated by the combined action of a coherent whistler-mode wave and a simultaneously observed electron beam with an energy range of the order of 1 keV [Reinleitner et al., 1982]. In order to seek a plausible generation mechanism and interpret this nonlinear phenomenon, a computer simulation study was carried out. The code used is a two and half dimension Electromagnetic Particle Code (EM2 code) following nonlinear motions of more than a half million superparticles in the 128 × 128 grid space under the self-consistent fields. The results show an interesting two-beam jetting due to a trapping and subsequent detrapping process, yielding a strong electrostatic emission with k vector parallel to the external magnetic field. The nonlinear evolutions of the wave spectra and of particle distribution functions and their phase-space behavior are discussed in connection with the observed ES bursts. (Computer simulation, electrostatic bursts, chorus hook, nonlinear particle trapping).
J. Geophys. Res., A, Paper 4A0326

4755 Plasma Instabilities
A NOTE ON THE SOUTHWOOD'S INSTABILITY CRITERION
C. Uberoi (Applied Mathematics Department, Indian Institute of Science, Bangalore, 560012)
It is shown that Southwood's instability criterion for the onset of Kelvin-Helmholtz instability at the magnetopause can be directly obtained from the marginal instability condition for the pure Alfven surface waves propagating along the interface between two incompressible media in the limit when the wave propagation direction is nearly perpendicular to the direction of the largest magnetic field. The phase velocity of the surface waves first excited at the onset of the instability depends on the angle between the interplanetary magnetic field and flow velocity in the solar wind in front of the bow shock. (Kelvin-Helmholtz instability, magnetopause, instability criterion, surface waves).
J. Geophys. Res., A, Paper 4A0393

5760 Plasma motion, convection, or circulation
LONGITUDINAL ASYMMETRY IN THE IO PLASMA TORUS
A. F. Cheng, H. T. Paonessa (Applied Physics Laboratory, The Johns Hopkins University, Laurel, MD 20707), C. G. Maclennan, L. J. Lanzerotti and T. P. Armstrong.
A clear inbound-outbound asymmetry is found in Voyager 1 Low Energy Charged Particle (LECP) phase space densities near 6 R_J. The asymmetry is of the same sign and comparable magnitude for electrons and ions at several different energies. Ion phase space density profiles at three values of the first invariant are uniformly displaced to larger radius by ~ 0.25 R_J during the inbound pass. Inbound-outbound asymmetries which are very similar for electrons and ions at many different energies can be accounted for naturally by a convection electric field in the plasma torus. If the asymmetry is attributed to a convection field fixed in local time, then the field has a component of ~ 4 mV/m pointing toward $01^h 20^m$ LT, roughly orthogonal to the dawn-dusk electric field proposed to account for local time asymmetry in the plasma torus. On the other hand, the asymmetry can be attributed to a corotating convection field, such that plasma outflow occurs within $170° < \lambda_{III} < 300°$ at a velocity of ~ 2×10^{-6} R_J s^{-1} near L = 6. In this case, the LECP observations would be consistent with the magnetic anomaly model. If asymmetric particle losses are responsible for the effect, then the ion loss rate was ~ 25% greater during the inbound pass.
J. Geophys. Res., A, Paper 4A0314

Seismology

6920 Explosion seismology
MODELING NEAR FIELD AND TELESEISMIC OBSERVATIONS FROM THE AMCHITKA TEST SITE
L. Burdick (Woodward-Clyde Consultants, Pasadena, CA 91109-3245), T. Wallace and T. Lay (Seismological Laboratory, California Institute of Technology, Pasadena, CA 91125)
During the Amchitka testing program, recordings were made of the near field ground velocity for events MILROW and CANNIKIN. These records exhibited a P arrival, a feature associated with near field pP and a developing Rayleigh wave. In this investigation simple models were found which match the complete seismograms. They simultaneously predict the amplitude, waveshape, timing and periodicity of both the body waves and the surface waves. Models for both the Amchitka crustal structure and the source time functions were developed. The crustal model is similar to previous models in its average properties, so travel time constraints are still satisfied. Small modifications have been made to match the waveform data. The events on Amchitka can apparently be represented as isotropic point sources with the types of simple source time histories predicted by classical yield scaling laws. A source model for event LONGSHOT was developed on the basis of the yield scaling laws since no near field records are available for it. The source models were tested by comparing the teleseismic body waveforms they predict with observations. Short period P waves, long period P waves, and long period pS waves were considered. The short period P waves provided the best constraint. To match them, it was necessary both to develop a model for teleseismic pP since it arrives later than the near field model would predict and to estimate the average value of t^*. The MILROW and CANNIKIN teleseismic short period P waves indicate that the average effective t_α^* for teleseismic raypaths from Amchitka is 0.9 s. The scatter about this value, however, is very substantial. The accuracy of the scaling laws was tested by comparing synthetics for LONGSHOT to teleseismic observations. The predicted amplitudes and waveshapes fall within the scatter in the observations though again this scatter is substantial.
J. Geophys. Res., B, Paper 4B0054

Geophysical Research Letters